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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Impact of urban parameterization on high resolution air quality forecast with the GEM – AQ model" *by* J. Struzewska and J. W. Kaminski

J. Struzewska and J. W. Kaminski

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We would like to thank Referee #2 for the review and valuable comments which will help to considerably improve the quality of the manuscript.

In order to address the main concerns about the "duration of the simulations and problems with the methodology employed in the work" we will make an effort to synthesise and present objectives, characteristics of the modelling system, and methodology so an overall model performance can be presented to the reader in one place. These changes and clarifications will be incorporated in the final submission.

Perhaps it was not stated clearly that the GEM-AQ model (Kaminski et al., 2008) is a numerical weather prediction model where air quality processes (gas phase and aerosols) are implemented on-line in the host meteorological model, the Global Environmental Multiscale model (Cote et al., 1998). For the presented research scenarios GEM-AQ was run in a non-interactive mode where chemical fields of prognostic greenhouse gases and aerosols calculated in the AQ modules were not used in the radiative transfer calculations of heating rates in the meteorological part of the modelling system. On the other hand, the TEB module was run on-line in an interactive mode where it contributed to the energy balance of the host meteorological model.

In terms of modelling domains and meteorological objective analysis (initial conditions), the system was formulated in a series of sequential runs. Initial conditions for prognostic meteorological variables were generated in a continuous objective analysis cycle using the GEM model to produce trial fields on a global grid with spacing ~35km. Objective analysis was done with the 4DVar method (Gauthier et al., 2007) (as stated on page 9524 line 15). Every 24 hours objective analysis fields were used to re-initialize the next stage, where GEM-AQ was run on a global variable resolution grid with spacing ~25km in the core (as shown in Fig 1a). Finally, GEM-AQ was self nested to run in a limited area configuration (LAM) at 0.0625 deg. The TEB module was active in the final nesting stage only. Thus, the suggestion to extend the "duration of the simulations" would result in a series of meteorologically independent 24 hour runs. It was not our objective to generate a large number of independent cases. In order to have a continuous simulation with the TEB module one would have to modify the assimilation system, i.e. generate GEM trial fields at sufficiently high resolution for the TEB module to be meaningful and provide observation of prognostic variables (or its proxies, i.e., radiances for temperature) from a high density observing network (i.e. satellite sensors). These requirements are simply beyond current computational and observing capabilities. However, high density observing networks, together with high resolution (temporal and spatial) LAM based assimilation systems, could be employed in specialized observing campaigns (i.e. page 9250 lines 15-18). We believe that our findings could contribute to the design and execution of such observing and modelling campaigns. The objective of our research was to present the impact of the TEB module in GEM-AQ for several cases representing different meteorological conditions (as stated on page 9518 line 9).

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Answers to individual comments

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Referee #2:

The paper describes a set of sensitivity simulations of an on-line air-quality model, in which an existing meteorological parameterization for radiative transfer in urban environments (the Town Energy Balance) was turned on or off and the effects on the meteorology and chemistry were noted. There are problems with the methodology employed in the work, which need to be addressed by the authors, as follows:

Main Issue with the paper: The authors state on page 9520 that changes in meteorological and air quality parameters due to urban effects were analysed extensively. An extensive analysis is one in which a large number of measurement stations (hundreds) are compared to model predictions, for both air-quality and meteorological parameters over a long time period (weeks to months, even up to and over a year). Good examples of these sort of studies include the model intercomparisons in North America for TexasAQ and ICARTT (McKeen et al papers), and the multi-model comparison of the AirQuality Model Evaluation International Initiative (AQMEII – see recent papers in Atmospheric Environment).

Authors:

We agree that “extensive analysis” was rather unfortunate term in the context of the presented research. The projects referred to by the Reviewer were carried out in a multi agency initiative as a joint effort of the modelling and measurement communities, while the presented work could be compared to short case studies presented in the

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literature.

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Referee #2:

These examples give some of the key methodologies for a comparison of models and their parameterizations:

Authors:

The model evaluation in terms of comparison with measurements is not the objective of the presented work. The forecast evaluation is done every year of the system operation. In such model performance assessment we do use statistical error measures such as: mean bias error, mean absolute gross error, RMSE, Pearson correlation, hit rate for exceedances of alarm threshold value and the Taylor diagram for visualization. Such an evaluation is done using observations from rural background and suburban air quality monitoring stations and was presented in reports and conference presentation listed below.

Struzewska J., Kaminski J.W., Durka P., Operational evaluation of a high resolution air quality forecast over Southern Poland, EGU General Assembly 2012

Struzewska J. and Kaminski J.W., Application of Model Output Statistics technique to a high resolution air quality forecast, EGU Assembly 2011

Regulski P., Struzewska J., Kaminski J.W., Szymankiewicz K., Distribution of PM10 concentrations over Southern Poland in winter period - observations and GEM-AQ model results, EGU Assembly 2011

Kaminski J.W., Struzewska J., Development And Performance Of A Semi-Operational Chemical Weather Forecasting System EcoForecast.EU, EGU Assembly 2011

Struzewska J., Kaminski J.W. Semi-operational air quality forecast for Poland and Central Europe with the GEM-AQ model. Proceedings of the 13th International Conference

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on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes, June 2010, ISBN 2-8681-5062-4

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Referee #2:

a. Large numbers of observation stations are compared to the models.

Authors:

As already mentioned, the evaluation for rural and suburban area is done routinely. In the case of the presented work we have focused on urban areas. A national air quality monitoring network in Poland is not mature and the number of urban stations is limited. Moreover, not all of these stations provide meteorological observations and the list of observed parameters is not standardized. We will present the comparison with a larger number of monitoring sites (urban background) for meteorological parameters and pollutants concentrations.

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Referee #2:

b. The comparisons are quantitative: standard measures of model performance are used (correlation coefficient, slope, intercept, mean bias, normalized mean bias, normalized mean error, root mean square error, index of agreement, etc.).

Authors:

The model (without urban parameterization) is evaluated on a regular basis against measurements for rural and suburban area using statistical error measures. For presented cases the length of the modelled record is too short to give statistically significant results.

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Referee #2:

c. The comparison is over a sufficiently long time period to allow these statistics to be meaningful (a few weeks in the case of measurement intensives, year-long simulations in the case of the AQMEII model intercomparison).

Authors:

The concept of the model evaluation framework of the AQMEII project includes not only the "operational evaluation", which does focus on the direct comparison of modelled results with the observations, but also the "diagnostic evaluation", which is to examine the response of a model to perturbations of the input fields based on sensitivity tests.

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Referee #2:

d. Analysis of episodes are done in the context of case studies, following the main analysis over the longer time period and across stations.

By comparison, in the authors' work, three tests of duration of a single day are used, and no statistical measures are made of the model's performance. No comparisons to observations for air pollutants are made. Qualitative comparisons to observations for only two meteorological variables are made (wind speed and temperature), at only three stations.

Authors:

As stated above, we will compare the results with available observations from air quality monitoring stations located in other cities (Poznan, Kielce, Kedzierzyn-Kozle, Opole, other stations from Wroclaw and Warsaw). Apart from the temperature and wind speed, we will add analysis for air pollutants concentrations. However, for smaller cities, or for stations located in the outer suburbs, the effect of the TEB parameterization might be negligible.

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Referee #2:

Comparisons between the different model scenarios are only made for image snapshots at particular hours – with no reasoning for why those hours were chosen.

Authors:

The idea behind this comparison was to assess the largest differences between "urban" and "non-urban" scenarios. The hour chosen for graphical visualization for each modelled case represents the largest impact of the TEB parameterisation on calculated temperature fields. We believe that the fact that maximum impact of urban cover differs depending on the weather pattern confirms that the physics behind the TEB parameterization works correctly and there are no unrealistic diurnal forces.

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Referee #2:

Insufficient analysis has been carried out for the authors to be able to state clearly whether the use of TEB has improved the model's air pollution or meteorological forecasts (Conclusions, page 9531, lines 9-11).

Authors:

At the given resolution we do not expect significant improvement of the model performance. Emission fluxes spatial distribution – the same in both scenarios - represents only general location of the emission sources. In the scenario with the TEB parameterization the description of the city (in a 5km grid) is far from being realistic. Measurements taken at urban background stations in most cases might not be representative for the results obtained in both scenarios. However, taking into account the area covered by cities in the domain, and the size of major cities as compared with grid resolution, it seems reasonable to include urban processes. The objective of the study was to

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investigate how significant will be the impact of urban parameterization on meteorological and air quality forecast, to assess if these changes are interpretable in terms of weather conditions and to indicate if there is a tendency to reduce the discrepancies between the model and the measurements taken in urban stations.

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Referee #2:

In order for the paper to be acceptable, the following work needs to be carried out: a. The authors need to run the model for a longer time period (at least a week, and preferably a month) for the original model and the two urban setups for the TEB.

Authors:

This has been addressed in the opening paragraph as well as on page 9524 line 15 i.e. "... fine scale meteorological characteristics that result from the TEB parameterization are not carried between simulations ... " where simulations are defined as 24-hour modelling periods that start from an objective analysis (meteorological initial conditions). The objective of our research was to study several cases only.

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Referee #2:

b. The observations and model values should be compared using standard statistical measures such as noted above.

Authors:

The objective of our research was to present the impact of the TEB module in GEM-AQ for several cases representing different meteorological conditions for short term meteorological and air quality forecast in the meso-gamma scale.

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Referee #2: c. The comparison to observations should be done for more than 3 stations, preferably with urban/suburban and rural stations separated out, to show the relative impacts in these different environments.

Authors:

We will extend the comparison to available urban background monitoring stations.

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Referee #2:

The main issue I have with the paper is that the duration of the simulations and the comparisons to observations are insufficient to be able to really conclude whether or not the TEB improves the model predictions. This needs to be addressed before I can recommend publication.

Authors:

The objective of our research was to present the impact of the TEB module in GEM-AQ for several cases representing different meteorological conditions for short term meteorological and air quality forecast in the meso-gamma scale.

In order to have a longer and continuous simulation with the TEB module the assimilation system would have to be modified. The GEM model (used in the assimilation cycle) would have to be run at sufficiently high resolution for the TEB module to be meaningful. This would require an implementation of a regional high resolution assimilation cycle. This level of effort is outside the scope of our paper and it is beyond our resources.

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Other issues:

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Referee #2:

(1) Urban-land use: the source of data for section 4.1 needs to be stated (e.g. are these based on observations by the authors, what database was used [aerial photographs, satellite mapping, surface based obs, etc.)? The connection between sections 4.1 and 4.2 is not clear. The authors need to: (a) state their reasoning for their choices of mix of urban land use classes UF1 and UF2;

Authors:

We have decided to reorganize Chapter 4 and combine sections 4.1 and 4.2 to make it more coherent. The description of selected cities in Poland given in section 4.1 is mainly based on the information obtained from Spatial Planning Offices and Town Development Departments.

As the differences between UF_1 and UF_2 scenarios were small and in fact UF_2 was not referred to in the analysis we decided to remove the information on this scenario and to focus on UF_1 description in terms of the input files preparation and the results analysis.

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Referee #2:

(b) state the connection to those choices and the observations made in 4.1;

Authors:

In Chapter 4 we will clarify how the information on the morphology of major cities in the computational domain was used to derive urban cover classes applied as input for the TEB module.

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(c) describe how these urban land cover choices were applied in the model. For example, was the given assumed fractionation on of building types from Table 2 used for all grid squares containing an urban land fraction, specifically modifying that fraction's surface properties? Another choice would be to have different TEB urban cover dependant on the relative fraction of urban land use in the grid square. This needs to be clarified in the text.

Authors:

As in the modelling domain there are quite a lot of cities and towns we have proposed a simplified approach to urban structure description. We have assumed that at the resolution of 5km each city could be described with three mutually exclusive categories: city center, middle suburbs and outer suburbs. This is stated in the introduction to Chapter 4. However, we will provide additional information to clarify the preparation of input data to the TEB module.

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Referee #2:

(2) Page 9524, line 10: a better phrase than "non-stationary" would be "time invariant"; the former implies motion in space, the latter a variation over time.

Authors:

We have used the term "non-stationary" to emphasise the fact that the process and parameters evolve in time and space. Such a term is adopted from the mathematical description in fluid dynamics.

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Referee #2:

(3) Page 9524, lines 19 to 22: more description of these three case studies should be carried out in the opening paragraphs of this section, along with reasoning as to why

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they are representative of the region.

Authors:

For this analysis we decided not to select extreme weather events or high pollution periods. We have selected 'average situations' representing autumn, winter and spring seasons, with a different temperature variability range. Also, we looked for different weather patterns (strong wind / moderate wind). Presented days give a good representation of circulation patterns over Central Europe for these seasons. We will emphasize this in the revised manuscript.

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Referee #2:

(4) Section 5.1. Figure 3 is incomplete in that it shows the difference between the different scenarios, but not the difference between each scenario and the version of the model which is not running the TEB code. This is necessary: the authors conclude that the differences between the scenarios is insignificant, but that can only be done in comparison to the differences for the same fields carried out with and without the TEB (i.e. as opposed to [(UF_2 – UF_1) = (UF_2 – original) – (UF_1 – original)], also show UF_2 – original and UF_1 – original. If the value of |UF_2 – UF_1| « |UF_2 – original| and |UF_1 – original|, then the impact of the two different scenarios can be said to be insignificant.

Authors:

We have decided to remove the analysis describing UF_1 vs. UF_2 and will focus on the description of UF_1 results. We will reorganize Chapter 4 and will provide a clear description on how urban layers were prepared. We will remove section 5.1 and Figure 3. Chapter 5 will be reorganized (pls. see below).

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Referee #2:

(5)Sections 5.2, 5.3, 5.4: In each of these case studies (which as noted above should follow a more detailed statistical analysis of the model performance), the authors base their analysis on comparisons of model runs with and without TEB. The figures (5, 6, 8, 9, 11,12) need improvement:

Authors:

In our reply to Reviewer #1 comments we have proposed the following changes in Chapter 5. To improve the paper we will:

-) Skip the description of the analysis of urban cover approach (UF_1 vs. UF_2) section 5.1 will be removed and we will focus on UF_1 results.

-) Reorganize Chapter 5 to include subchapters for each case – with three sections – case description / sensitivity study / evaluation.

-) We will add a description of modelling results in terms of meteorological patterns over the area of interest as well as pollutant concentrations.

-) We will consider expanding the analysis presenting the vertical structure of temperature and selected pollutant concentrations.

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Referee #2:

a. Each set of two panels should also show the non-urban scenario values – allowing the authors to demonstrate to the reader the relative magnitude of the anomaly compared to the base case unmodified model.

Authors:

We can incorporate additional figures. However, taking into account the range of the variability of different parameters in the domain, the visual differences between urban

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and non-urban simulations for individual parameters are not large. That was the main reason for our approach to present anomalies only. Adding two figures for each parameter (temperature, wind speed, air quality species) and for each analysed day would increase the number of plots by 12. We believe that a plot showing reference to the non-urban scenario will be sufficient.

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Referee #2:

b. All colour scales should include units of the field being displayed.

Authors:

We will add units to the colour scale.

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Referee #2:

c. Font size on the colour bar keys should be increased. Figures 5 & 6 have different snap-shot times, while 8 & 9, 10 & 11 were for the same time – why? Were the authors looking for the maximum impact during the time span (this should be stated in the text if so).

Authors:

Figures 5 and 6 were generated for 15 UTC. In the description of Figure 5 there is a typographical error (05:00 UTC instead of 15:00 UTC).

For each day we have presented results for hours at which the impact of urban structure on modelled temperature was most evident. We will add such a statement in the revised text.

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Referee #2:

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(6) Page 9527, line16: “lack of this effect” not clear which effect the authors are referring to, here. Perhaps the lack of UHI in the non-urban run?

Authors:

The language of this paragraph will be improved.

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Referee #2:

(7) Section 5.5: a. Section title should be “Comparison with meteorological measurements”. Are any air pollution measurements available? The authors need to give more justification as to why these three stations were used – in what way are they representative of the area? Were no other station data available?

Authors:

The idea of the comparison was to use urban background monitoring stations from the national air quality monitoring network. We have selected stations measuring both meteorological parameters (not all stations carry out meteorological observations) and air pollutants concentrations. We have chosen three cities in which urban effects were most noticeable in our experiments. As already mentioned, for the evaluation we will add more stations located in other major cities present in the domain, and we will analyse pollutant concentrations.

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Referee #2:

b. Figure 13 (or a companion figure) should also show the equivalent panels for the non-TEB simulation.

Authors:

We will add plots suggested by the Reviewer. Alternatively, we will prepare plots that

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include both urban and non-urban simulations results combined on one graph.

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Referee #2:

c. Either on the figures, or in an accompanying table, the authors should give the statistical summary numbers for each day (see point 1 for the metrics to be applied): did the TEB improve the forecast?

Authors:

Taking into account that for a single station for each day the length of the analysed records has 24 elements, the statistical significance of the error measures will be questionable. We will consider presenting error measures averaged over all sites included in the comparison.

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Referee #2:

(8)Conclusions: a. Page 9259, line 19: “In each case”: here, “case” could be taken to mean either the scenario (UHI or not) or the simulated day. Maybe “In each period simulated”?

Authors:

The language of this paragraph will be improved.

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Referee #2:

b. Its not clear why the authors believe only two factors could influence the results. For example, the stability of the PBL in the surrounding (non-urban-influenced) environment could also play a role.

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Authors:

The Reviewer raised a very interesting question concerning the spatial extent of the urban impact on PBL thermal structure and in consequence on dispersion conditions. Such investigation should be undertaken for idealised case to separate effects due to advection from thermally induces vertical motion. A passive traces study would also be interesting.

As for technical issue - in the on-line model the concept of the PBL height is not employed in tracer dispersion – vertical diffusion coefficient calculated in the meteorological host model are used directly in the vertical diffusion equation for tracers.

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Referee #2:

What about the building height distribution, or the assumed thermal properties of the buildings themselves? i.e. there needs to be a justification for why the authors feel these two factors are the most likely to influence their results. Note that on the next page (9530, line 13), the authors mention the role of stability vis-à-vis the impact of increased surface temperatures on stability: if the atmosphere is already unstable, is the UHI likely to have a significant impact?

Authors:

In general, we agree with the reviewer that assumptions on the parameters such as building height, and radiative properties of urban cover play an important role in the modelled urban energy balance. However, at the resolution of ~5km the city is represented very roughly and an “average city cover” in a grid square will hardly be representative for specific streets and buildings located within the grid square. Moreover, the modelling domain covers area of 800x800 km and detailed analysis for all the cities present in the domain are not feasible.

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Referee #2:

c. Page 9530, lines 25-27: “might indicate”: I have seen other papers in which the anthropogenic energy release was up to 100 W/m2: how representative of the range of values are the standard values in the TEB?

Authors:

AHF phenomenon has a significant impact on urban energy balance; however, reliable estimation of AHF is difficult. The magnitude of AHF fluxes reported in the literature usually ranges from ∼100 W/m2 in the city centres to ∼10 W/m2 in the low-density residential areas. According to Klysik (1996), the anthropogenic heat flux in Lodz was estimated to be 12 W/m2 during summertime and 54 W/m2 during wintertime. AHF calculated for the winter period for Poznan by Bagienski (2006) was 77 W/m2 for suburbs with domestic heating and 35 W/m2 for suburbs with central heating.

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Referee #2:

How well do they represent heat emissions in the region simulated? d. Page 9530, line 28 to page 9531, line 1: this needs to be demonstrated quantitatively, see earlier comments.

Authors:

The default AHF values set in TEB seem to be slightly underestimated. Recently a sensitivity study was undertaken to analyze changes of the surface temperature due to anthropogenic heat flux variations for the area of Krakow with the resolution of 1 km. The outcome from this study will be presented at the EMS 2012 conference in September (Durka et al., 2012).

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 9517, 2012.

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