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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The 'urban meteorology island': a multi-model ensemble analysis" *by* Jan Karlický et al.

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We would like to thank to Anonymous Referee #1 for all comments, suggestions and corrections in his review of our manuscript. They cover issues which were resolved in the initial review, therefore they have been already taken into account by the authors and incorporated into the text. Nevertheless, we provide our point-by-point responses here too:

Referee's Comment #1: Abstract: the abstract should mention that you only study European cities. In terms of morphology they are substantially different North American cities that this caveat makes sense to mention.

Author's response: Corrected.

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Discussion paper

Referee's Comment #2: Abstract: you indicate that there is a substantial sensitivity of the model to the selected PBL schemes and urban canopy scheme. It would be more attractive for the reader if you can add a recommendation which settings are preferred.

Author's response: The primary task of the paper was not to provide an optimal model setup to describe urban climate but rather to examine the sensitivity of the modelled urban climate and its contrast with urban vicinity to different models and model configurations. Nevertheless, we added a such 'recommendation' to the discussion and conclusion based on Fig. 3, 4 and 5.

Referee's Comment #3: Ln 12: choice => selection

Author's response: Corrected.

Referee's Comment #4: Ln 13: hyphenation: boundary-layer scheme

Author's response: Corrected.

Referee's Comment #5: Ln 31: hyphenation: boundary-layer structure

Author's response: Corrected.

Referee's Comment #6: Ln 59: hyphenation: boundary-layer turbulence. Please check the manuscript throughout.

Author's response: Corrected everywhere.

Referee's Comment #7: Ln 76: model resolution of 9 km: defend why this is sufficient to represent cities sufficiently. The resolved scales will be 5 * 9 km = 45 km, which means only cities ofthat scale are appropriately resolved, but there are not that many cities in Europe ofthat scale. I the feeling the cities on Belgium and Hungary are larger in your Fig. 1 than in reality.

Author's response: As mentioned in the manuscript, the urban land-use is differently represented in WRF and RegCM: in RegCM it is defined as fractional landuse which

allows even small urban areas to be resolved as fractions of the 9km×9km grid-box. In WRF, grid-box is considered 'urban', when the urban land-use has the highest fraction, i.e. it does not have to be strictly over 50 % of grid-box area. Moreover, urban land-cover can be increased by small towns and villages located in the grid-box near the city, which seemingly increase the city size. However, big cities such as Berlin, Prague, Warsaw or Budapest, analysed in this paper, are covering multiple model grid-boxes themselves and thus are represented sufficiently even at 9km×9km resolution.

Referee's Comment #8: Ln 78: 2015–2016: please defend why these years have been selected. 2015 is a rather warm year in Europe, so how representative is the selected period.

Author's response: Indeed, 2015 is a warmer year than average (not so for 2016) (https://climate.copernicus.eu/european-temperature). However, years 2015 and 2016 are comparable to other years in the last decade (e.g. 2014, 2018) for Europe. Moreover, the variability of the local climate characteristic for individual cities chosen in the study is certainly larger (e.g. Hamburg with about 8° C annual average temperature versus Beograd 12° C; source: climate-data.org) than the year to year variability of the average European climate. We thus conclude that the spread of the magnitude of the urban meteorological effects and the 'urban meteorology island' given by considering a wide range of cities is well above the spread given by choosing different years during recent decade.

Referee's Comment #9: Ln 85: please add some sentences that defend why you have selected these schemes. I expect you have not selected them randomly but that there was a certain strategy or you built upon earlier studies.

Author's response: The selection is based on the availability of the schemes and the restrictions for their different combinations as well as on the expected impact on the 'urban meteorology island'. For WRF: BEP+BEM urban model works only with MYJ and Boulac PBL schemes combined with the Noah land-surface model. The MYJ PBL

scheme works only with Eta surface-layer scheme (see e.g. WRF-ARW user's guide). Further, schemes usable in WRF-Chem model with indirect aerosol effect are tested (Purdue Lin microphysics scheme) and those that enable cumulus radiation feedback (listed convective schemes). These simulations are planned to be used in a following study with the radiative feedback of the emissions from the selected cities. The RRTMG radiation scheme was chosen as an efficient radiative transfer model that is fast yet has sufficient complexity. For RegCM: two PBL schemes are available (Holtslag and UW) so these were altered as the PBL model description greatly influences the meteorology in the urban canopy. Further, the two most widely used convective schemes were tested, the Grell and Tiedtke schemes with the consideration that convection is an important process that removes heat and moisture from urban areas influencing urban climate. Finally, three microphysical schemes are available in RegCM (for the used version 4.7) and these were combined with the PBL and cumulus schemes. The urban canopy model could not be altered as only the CLM4.5/CLMU was available for RegCM simulations.

Referee's Comment #10: Table 1: elaborate the table caption. The caption should be placed above the table. Idem for Table 2 and 4.

Author's response: Changed for all tables.

Referee's Comment #11: Table 1: please add a sentence that elaborates on the experiment abbreviations.E.g. the "E1U1L82C5" is not naturally related to the <SLUCM, 40, BouLac, Eta, Grell-3D> experiment. All experiment abbreviations start with "E1" so E1 can be removed. Idem for Table 2

Author's response: E1 is removed from all abbreviations, added 'W' on the beginning in Table 1, denoting WRF model, similarly to RegCM model in Table 2. Changed in all tables and figures, including the text.

Referee's Comment #12: Ln 118: simulations with MYJ PBL and Eta SFL schemes give notable underesti-mations (up to 2 deg C): link to literature, this MYJ behaviour is

well known.

Author's response: This feature is commented and referenced (by Zhong et al., 2017) in the first paragraph of the Discussion section.

Referee's Comment #13: Figure 3: I have reservations against figure 3. Not about the contents but about the plot type. Now the results are shown as time series or at least the lines connect the different experiments. However there are no links between the connected experiments.So the results should be presented differently, e.g. as bar graphs. Idem for Fig 6.

Author's response: X-axis does not mean time axis automatically, lines between points are removed from the plot, points are enlarged (Fig. 3 and 6).

Referee's Comment #14: Ln 124: Daily ECAD values from selected stations are used for more detailed model validation over european urban areas, which are the main focus of the paper:European should be capitalized.

Author's response: Remark accepted.

Referee's Comment #15: Figure 4: please label all figure a,b,c, etc. This is much more easy for referencing

Author's response: We believe that subplots are sufficiently denoted by variable names and statistical quantities, but in any case, the publisher places "a)", "b)" etc. subplot indicators, automatically during the typesetting process (including placement in the figures caption).

Referee's Comment #16: Figure 4: panel T2max and SWDOWN should have an y axis that is better adjusted(less wide range) to the data.

Author's response: Comment accepted. Figure 4 modified.

Referee's Comment #17: Figure 4: in columns 2 and 3 it is very difficult to see what are the differences between the runs. Better to start the y axis at a much higher value.

Idem for Fig 5.

Author's response: Comment accepted. Figures 4 and 5 are modified.

Referee's Comment #18: Figure 4 and 5: if these statistics are averaged over all cities in Table 3, it remains unclear how they are influenced by certain sites or not.

Author's response: We are unsure if we understand the reviewer's comment properly. We tried to avoid a city-by-city validation to present rather the all-city-averages, which gives an indication of how the models are able to capture the urban climate for cities from an entire region. It is clear that models are more successful for some cities and less for others, but our aim is not to present individual city statistics.

Referee's Comment #19: Fig 8 and 9: the header "surface heat island" is misleading since this is not plotted according to the caption. Furthermore I do not understand what is the functionality of these plots if you only show satellite data.

Author's response: The header of Fig. 8 and 9 is "Surface urban heat island" as we plotted the surface temperatures (or skin-temperatures). The goal of presenting these two figures was to show the urban impact on surface temperature seen by remote sensing methods (satellites in this case). SUHI is a major component of what we call 'urban meteorological island' in our paper and we therefore decided to also show some observational based evidence of this component. Satellite measurements have the great advantage of showing the spatial distribution of the measured quantity in contrast with e.g. station based data.

Referee's Comment #20: Ln 198: please be more precise here: about which temperature are writing here. Itis daily mean T2m?

Author's response: Yes, they are daily means of T2m during summer and winter season. The information has been added into the text.

Referee's Comment #21: Ln 202: absolute humidity is the density of the vapour pressure so unit should be g/m3

Author's response: Following the Meteorological Glossary of American Meteorological Society, we changed it to "specific humidity", which describes mixing ratio, independent to adiabatic expansion or compression, and can be measured in kg kg−1 (i.e. it is dimensionless).

Referee's Comment #22: Ln 333: it is unclear whether the statement of BEP+BEM is an advertisement for this scheme or not. Is this scheme the best, despite the biases you report about?

Author's response: It is not easy to say whether the BEP+BEM is better or not – it produces greater biases in temperature but smaller biases in wind speed in comparison to other schemes.

Referee's Comment #23: Ln 349: I have the feeling the authors are somehow too positive about the satellite data. As far as I understand them, they can only be applied for cloud free days, and this does not occur very often, so they may give a biased picture. Please comment.

Author's response: Yes, surface temperature is measured only during clear-sky days by satellites, but over this fact, it still gives useful insight in surface temperature distribution around large cities, thus demonstrating the main component of the 'urban meteorology island' using remote sensing based data, which enables observation over larger areas rather than point measurements. The information about clear-sky days is added to the text.

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