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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Regional climate model assessment of the urban land-surface forcing over central Europe" *by* P. Huszar et al.

P. Huszar et al.

huszarpet@gmail.com

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Response to Referee 1's comments

Review: *Huszar et al., Regional climate model assessment of the urban land-surface forcing over central Europe*

Dear Referee,

thank you very much for your valuable comments. We found them very important and we tried to take each of them into account. Our responses follow point-by-point

- *Comment: My major concern with this study is the physical explanation of the results. I do not understand why the results relating to temperature and turbulence (temperature and mixing-layer height) show a wide-spread increase all over Europe while the results related to the water budget (evaporation, absolute humidity and precipitation) only show a localized decrease over the cities. This needs a proper explanation in the manuscript.*

  Authors' response:

  The wide-spread change of a given variable due to urbanization is, in general, related to the surface sub-grid treatment in our model. The surface model runs at a 2 km x 2 km resolution while the "dynamical" model resolution is 10 km x 10 km. The impact on 10 x 10 km resolution, which is shown throughout the manuscript, can be thus viewed as the superposition of the impacts over 2 km x 2 km sub-grid boxes. In nearly each grid box there is at least one urbanized 2 km x 2 km sub-grid box (except over the sea in the northwestern corner of the domain and in south next to Italy). The simulated temperature and turbulence related changes and those of humidity are directly connected to the surface characteristics and thus their perturbation due to urbanization is higher where the model grid is composed of more urban sub-grids. This is seen e.g. over large cities. So we cannot agree that in case of humidity, the decrease is localized. It is only magnified by denser urban sub-grid coverage.

  Where we found only localized effects is the precipitation. However, it is subject by high spatial and temporal variability, especially during summer when precipitation over central Europe is mainly of convective nature. Therefore the impact is seen and found significant only over the most affected areas, i.e. over gridboxes with high percentage of urban coverage corresponding to large cities. However, setting lower treshold for the significance (e.g. 90%), impact (mainly decrease) is detected over rural areas as well.

- *Comment: A related point is the urban cool island which is mentioned in the* *introduction. It would have been interesting to see whether the model is able to reproduce this feature or if this is lost in the overall warming produced by the model. The only hint is given in Fig. 12 which shows this effect in the measured data but it is not reproduced in the model. Fig. 12 has to be discussed in this respect.*

Authors' response:

Indeed, the Urban Cool Island effect is reproduced in our simulations but is rather weak. Although it is hard to recognize from Figure 11, during morning hours from 9 am to 12 am the curve representing the SLUCM simulation for the city center is slightly colder than the "vicinity" curve. Quantitatively, it is colder by -0.05 to -0.1 K. For Prague, the UCI is about -0.05 K on average. This is much less than the measured -0.2 to -0.3 K. The explanation can be in inappropriate urban parameters set for Prague. The domain wide parameters are representative for a typical central European city while the very center of Prague is characterized by more narrow streets than this domain average. In conclusion, having wider street canyons, the morning cooling caused by building shadowing is not strong, bringing less pronounced UCI.

To gain spatial information about the UCI, we evaluated the urban impact for summer 8–11 am (see attached figure). This figure clearly reveals the UCI effect. The modelled urban impact is negative in many cases, or at least the overall warming is suppressed or is not statistically significant, which is the results of the competing effect of the UCI and the overall domain-wide warming.

The UCI related results are now commented upon in more detail in the revised manuscript and the aforementioned figure is added in the manuscript as well (Fig. 14 in the revised manuscript).

- *Comment: The results for wind are mainly inconclusive. Most parts of the results did not pass the statistical significance test. What remains is an increase*

in summer nights and a decrease in winter nights over the cities. Once again, no convincing physical explanation is given. Local secondary flow circulations driven by urban heat islands (this is what the authors assume that it could be the reason) are usually small-scale and are most likely not resolved on a 10 by 10 km grid. The winter-time nocturnal decrease is not interpreted at all. A possible explanation could be quite different and is once again related to the simulated temperature response. A night-time cooling in winter leads to a stronger thermal stability of the PBL and thus to reduced 10 m winds. Likewise a night-time warming in summer leads to a less stable PBL and thus to an increase of 10 m winds.

Authors' response:

By replacing the criticized t-test in case of wind speed and precipitation with the sing-test, the significance of the results for wind slightly increased, but the overall picture did not change. We extended the explanation of the modelled wind speed changes. In both winter and summer daytime a slight decrease over cities is modelled. Similar decreases were found by Klaić et al. (2002) or Hou et al. (2013) and we attributed it – in line with previous studies – to increased roughness of the surface. Such urbanization related wind stilling was documented even on global scale by Vautard et al. (2010) analyzing the Northern Hemispheric observed winds. Another factor influencing the urbanization impact on wind is the destabilization of urban boundary layer (UBL) due to higher urban temperatures (seen also in connection with the PBL increase) which on the other hand leads to enhanced winds. These competing effects may result in slight wind speed decrease over cities and a small wind speed increase around these areas during daytime conditions.

The increase in wind speed during night-time in summer can be related to decreased nocturnal stability due to the presence of UHI. Another contributing factor is related to the urban-breeze circulation, when, in the presence of thermally induced horizontal pressure gradient, convergent motions towards the city form (Hidalgo et al., 2010), but we agree, that this local scale circulation pattern probably cannot be resolved with our resolution of 10 km x 10 km; most of the modelling studies dealing with this phenomenon used much finer resolution. E.g. the mentioned study calculated on a 500 m x 500 m resolution grid.

Enhanced roughness in urban environment may play a governing factor in the winter nightime decrease of winds, resulting also in lower PBL height modelled. A different summer nocturnal behavior is simulated for northern Italy (urban areas within the Po valley). Here, even in summer night time, wind speed decrease is modelled, again, probably governed by increased surface drag. A similar result was found for another southern city, Lisbon (Portugal) recently by Lopes et al. (2012).

The above mentioned explanatory paragraphs were added to the discussion in the revised manuscript.

- *Comment: The only vertical profiles from the simulation are shown in Fig. 9. They show the destabilization of the atmosphere during day and night in summer. This should lead to more thermal convection and more convective precipitation. It would be interesting to learn whether there is a shift in the model from large-scale precipitation to more convective precipitation in summer. In this context the abilities and effectiveness of the convection parameterization in the RegCM4.2 model have to be discussed.*

  Authors' response:

  Indeed, we found in our simulations a widespread warming in the PBL as well as a specific humidity decrease (which we do not present in the manuscript). This results in higher lapse rates, destabilization of the atmosphere leading to more thermal convection. By looking at the precipitation changes decomposed to large scale and convection portion, we see no significant change in the first

one, i.e. the simulated total precipitation changes presented in the manuscript correspond mostly to convective precipitation decrease. We use the Grell convective scheme (Grell, 1993) with the Fritsch and Chappell closure (Fritsch and Chappell, 1980). In this approach, precipitation rate is proportional to the updraft mass flux which is further proportional to the buoyant energy available for convection (ABE). With higher lapse rate the ABE increases but lower humidity in the PBL is counteracting. In our simulations, this latter effect dominates. In summary, reduced evaporation and consequently reduced humidity in the PBL provides less available moisture to convection which in turn drives the simulated precipitation changes.

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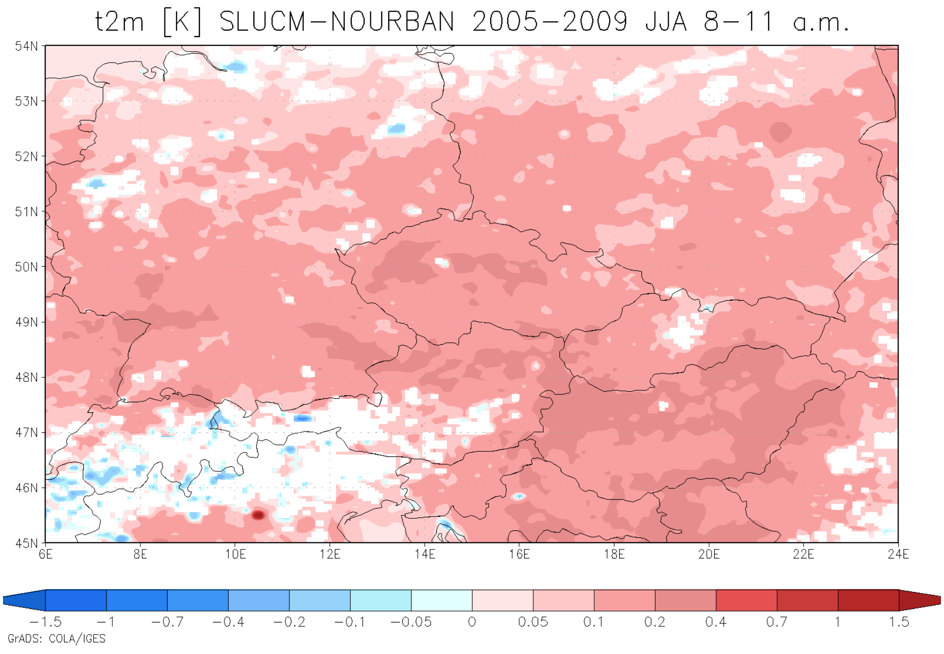

Fig. 1.