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Review

of the Doctoral thesis "**The effects of urbanization and atmospheric chemistry in climate modelling**" by **Jan Karlický**.

Importance of research topic

In his thesis Mr. Jan Karlický investigates the influence of urban land surface in terms of regional climate modelling. The topics discussed in the thesis, urban climate, regional climate modelling and pollution of urban areas are themselves important research topics nowadays and their combined analysis holds more value. With the already visible climate change it is important to gain as much knowledge as possible on modelling possibilities not only on the natural environment but on urban areas as well. Since the increasing temperatures have a further impact on the already warmer cities which has a negative effect on human health in extreme events, urban studies are especially important. The urbanisation however not only affects the meteorological conditions around us but it has a detrimental effect on air quality as well, which also negatively affects the vegetation surrounding the cities and the inhabitants alike. The possible future effects can only be estimated within a reliable range if the current conditions are well captured by models.

Though the computing capacities are continuously increasing, the climate models still have large computing and data storage demands, even if regional climate models are used. Therefore still, nowadays the 10 km horizontal resolution is preferred in regional climate modelling studies. At this resolution however the question arises whether the urbanisation effect can be studied. In his thesis Mr. Jan Karlický makes an attempt to answer the aforementioned question.

General remarks

The thesis is well-structured, though there are some chemical and chemical transport modelling descriptions that are superfluous considering the short, 5 pages long analysis of the atmospheric chemical model results. The cited literature in the introduction part could have been more recent, but in the result discussion sections this is balanced out. The description and introduction of results is building up from the least complex to the more complex simulations and even there are sometimes substantial differences in the modelling techniques the chapters are linked together creating a cohesive structure. The format of the thesis is the standard scientific report as expected. The results are presented on good quality figures, summarising the main results. There are no significant typesetting and grammar errors.

Results

The first results chapter (Chapter 3) discusses a short, 1-year sensitivity study of the used regional climate model to assess the initial modelling errors of the meteorological conditions. In regional climate modelling it is important to create such studies for each studied region, because the frequency and type of synoptic- and meso-scale phenomena differs from region-to-region so one cannot reliably use model setups validated for different regions. Not to mention that different model versions can also have large differences even with the same setup. The found modelling errors are in par with other European studies with the used WRF model.

The second results chapter (Chapter 4) is the main focal point of the thesis results, discussing the effect of urban surfaces to different meteorological variables. In the analysis three cities are studied, Berlin, Munich and Prague with different model setups using the WRF and RegCM models. Not only the capability of the model to reproduce the urban heat island is analysed, but also urban parameterizations of different complexity. The analysis on ventilation effect in Prague is a good addition to the discussion of the results as it is not just a direct analysis of model outputs. It is especially interesting that this analysis shows the importance of the boundary layer height calculation, which analysis is usually neglected as its verification – and sometimes its interpretation – is difficult.

The third results chapter (Chapter 5) shows the effect of added atmospheric chemical processes. Considering that the simulation covers one year, it would have been informative to compare the results with a similar one year simulation without chemical processes when analysing the meteorological variables. In the chapter, the concentrations of three atmospheric constituents, the O_3, NO_2 and SO_2 are considered as they are important greenhouse gases and it is theorised that their concentrations could be simulated well within reason at 25 km horizontal resolution.

Remarks on result discussions

Chapter 3

Model validation was carried out on a 25 km horizontal resolution, whereas in the next chapter, 10 km resolution is used. The "ideal" model setup can differ between these resolutions.

Chapter 4

It is shown that for this climate model setup, urban thermal characteristics are simulated the worst when using the most complex urban parameterization scheme. The author also notes that this is in contrast to other studies (e.g. Trusilova et al. (2016)), but what is missing from the interpretation is that in the referred article simulations were carried out on a 1 km horizontal resolution. The latter requires non-hydrostatic formulation of the dynamical processes as opposed to the hydrostatic approximation used in this thesis, which has a large impact on turbulence calculation and hence near surface temperature simulation. So it has to be emphasised that the conclusion that one wouldn't need complex urban process description is only valid for this 10 km resolution. Also, it is important to note that only one station was considered in each city to represent city conditions. If one would take true inner city measurements it is possible that the modelled urban heat island intensity would be underestimated.

Chapter 5

It is written that the ozone concentrations are well correlated but in hindsight and despite the extensive chemical introduction, it is neglected that the ozone formation process has a natural daily and seasonal cycle as it depends on the solar radiation. Since in general, the solar radiation is well simulated in all models, diurnal and seasonal variations of ozone are expected to be good.

It is also noted in the thesis that "overestimation of ozone at non-rural stations can be explained by model resolution…", however urban ozone concentrations are more overestimated than rural one according to the presented results. Also rural estimation of NO_2 and SO_2 are closer to observations than their urban counterparts which is also connected to the issue of incorrect emission data – partly due to resolution – which concern is noted briefly in the thesis conclusion.

Conclusion of results

In regional climate modelling it is difficult to pin-point one or two exact new results given the complex nature of climate simulations. Even though regional climate simulations were carried out before for this region in the ENSEMBLES or in the CORDEX projects, Mr. Jan Karlický created new simulations with different model setup hence every result could be considered as new scientific results.

Considering the results, in general one can infer that a) the meteorological effects of urban areas can already be analysed using 10 km resolution adequately, b) chemical composition requires higher resolution than the regional climate models currently offer. Both main outcomes are important to the global climate modelling community and not just locally.

- The former result suggest that though sometimes it is argued, in order to study urban effects high resolution (< 5 km) simulations are not necessarily needed, especially considering the uncertainty of climate scenarios, which decreases the high computation demand on urban climate studies.
- The latter result however shows the opposite, that in order to get a grasp on urban atmospheric chemistry, regional climate model resolution is not well suited. This also encourages the modelling community for further investigations and model development and shows the need for improved chemical input database.

The idea to assess urban climate at 10 km resolution could have been a vain effort but as the presented results show, it has paid off. Taking into account that surface characteristics define near surface temperature a simple difference in land use is expected to show its effects, but for a smaller city (at 10 km resolution) like Prague it is not a given that those effects can be maintained. The thesis work however shows that even minor spatial changes – compared to the domain size – in land use can be analysed. It is also important to note that it is shown, that these effects are not restricted to the surface but can propagate up to 2 km height even in a hydrostatic model.

The publication list of Mr. Jan Karlický shows that all presented results have already been published in prestigious peer-review journals exhibiting the importance and validity of his research.

Combining the publication work with the amount and skill of work needed to create the simulations and analyse the results proves Mr. Jan Karlický's ability to create scientific work. In a conclusion, **I recommend to accept the thesis** for doctoral exam.

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