Chapter 70
Assessing Climate Change in Cities Using UrbClim

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Abstract The urban heat island effect, in which air temperatures tend to be higher in urban environments than in rural areas, is known to exacerbate the heat impact on population health. We introduce a new urban climate model, further referred to as UrbClim, designed to study the urban heat island effect at a spatial resolution of a few hundred metres. Despite its simplicity, UrbClim is found to be of the same level of accuracy as more sophisticated models, while also being much faster than high-resolution mesoscale climate models. Because of that, the model is well suited for long time integrations, in particular for applications in urban climate projections. In this contribution, we present temperature maps for London, including an assessment of the present-day climate, and projections for the future (2081–2100).

70.1 Introduction

There is increasing concern regarding the impact of global climate change on cities. Together with drought and flooding, extreme heat stress is perceived as a problem that may turn really bad if no action is taken (IPCC 2014). Indeed, climate projections indicate that extreme heat waves, as that occurring in 2003 in Europe, are expected to become more commonplace towards the end of the century (Meehl et al. 2004; Schär et al. 2004).

Cities experience an additional heat stress due the urban heat island (UHI) effect, in which air temperatures tend to be higher in urban environments than in rural areas. Moreover, during heat waves the urban heat island appears to increase (De Ridder et al. 2011; Li et al. 2013), and hence the heat-related impact on population health is exacerbated in urban areas. Including urban heat island effects in the

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formulation of heat warnings and climate change adaptation plans is therefore essential and part of a sustainable urban development in general.

Yet, little or no information is available regarding future urban climate. Especially, climate projections at the scale of urban agglomerations are lacking, which is in part related to the computational constraints fine-scale climate models are facing. In order to remedy this, a new urban climate model (UrbClim) was developed. In this study, this new UrbClim model simulates the urban climate for a reference period (1986–2005) and a far future period (2081–2100) for eight cities under the strongest climate scenario of the IPCC (RCP8.5), by coupling it to the model output of eleven global climate models.

70.2 The UrbClim Model

An important difficulty often encountered with typical numerical climate models is the limited resolution and long integration time, making them difficult to use when studying urban and intra-urban variations especially in the context of climate change. In this contribution, we will present a new urban climate model, further referred to as UrbClim, designed to cover agglomeration-scale domains at a spatial resolution of a few hundred metres (De Ridder et al. 2014). The model scales large-scale weather conditions down to agglomeration-scale and computes the impact of urban development on the most important weather parameters, such as temperature and humidity. UrbClim is composed of a land surface scheme describing the physics of energy and water exchange between the soil and the atmosphere in the city, coupled to a 3D atmospheric boundary layer module. The atmospheric conditions far away from the city centre are fixed by meteorological input data, while local terrain and surface data influences the heat fluxes and evaporation within the urban boundaries. The primary output consists of hourly air temperature and apparent air temperature maps with a spatial resolution of 250 or 500 m.

Despite its simplicity, UrbClim is found to be of the same level of accuracy as more sophisticated models. The model has been subjected to exhaustive validation, and model results have been compared with hourly temperature measurements for, amongst other, London (UK), Bilbao (Spain) and Paris (France) (De Ridder et al. 2011, 2014b; Keramitsoglou et al. 2012). At the same time, the urban boundary layer climate model is faster than high-resolution mesoscale climate models by at least two orders of magnitude. Because of that, the model is well suited for long time integrations, in particular for applications in urban climate projections.

70.3 Urban Climate Projections

Within the EU RAMSES and NACLIM projects, urban climate projections have been set up for eight cities on three different continents (Almada/Lisbon, Antwerp, London, Bilbao, Berlin, New York, Rio De Janeiro and Skopje) (Hooyberghs et al. 2015). The methodology consists of a two-step process, in which at first the current urban climate in these cities is assessed, and only thereafter the climate projections are implemented.

To assess the current-day situation, the UrbClim model is coupled to ERA-Interim reanalysis data for the period 1986–2005. Since we are mainly interested in warm episodes, we make maps of the temperature during hot summer nights or days. As an example, in Fig. 70.1 we show the 95th percentile of the minimal temperature during the period 1986–2005, i.e. the temperature that is exceeded on average during four nights each year, for the city of Antwerp (Belgium). In this way, we identify the city districts which are, at present, most vulnerable to excess heat stress.

Furthermore, a coupling has been established between UrbClim and the output of global climate models, allowing the assessment of the urban heat island effects under future climate conditions. Within this study, we employed the business-as-usual RCP8.5 scenario of the IPCC and used the output of 11 global climate models to assess the climatic conditions in cities at the end of the current century. The coupling is described in detail in Lauwaet et al. (2015). Figure 70.2 compares the current and the future climate in London, by showing the 95th percentile of the minimal temperature for both the reference period (1986–2005) and

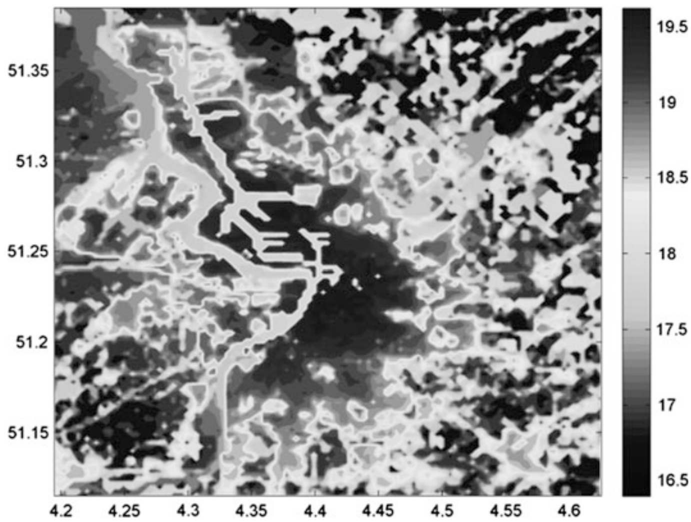

Fig. 70.1 95th percentile of the minimal temperature in Antwerp during the period 1986–2005. Higher temperatures are observed in the city centre (dark spots in the middle of the figure), while lower temperatures are observed in the rural areas (dark spots close to the edges of the figure)

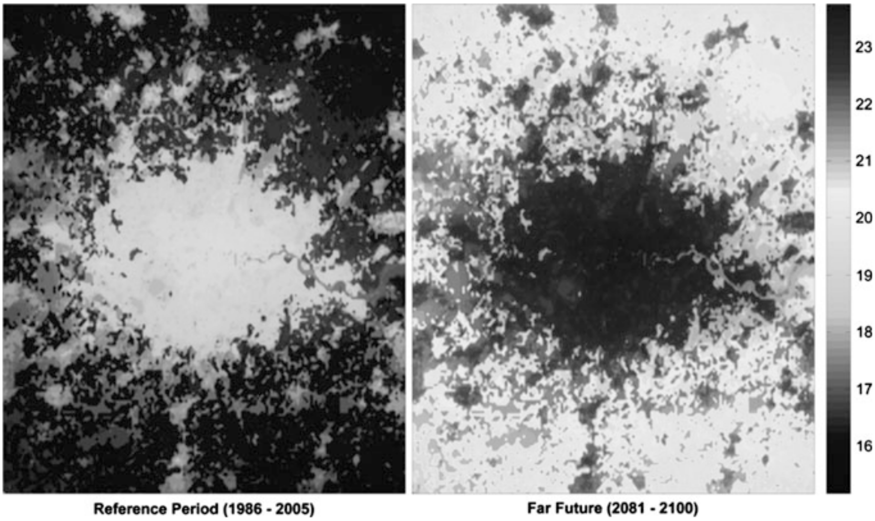

Fig. 70.2 95th percentile of the minimal temperature in London during the period 1986–2005 and during the period 2081–2100. Temperatures in the city centre are around 20 °C during the reference period and rise to 23 °C at the end of the 21th century

the far future (2081–2100). Clearly, there is a large temperature increase: future rural temperatures are comparable to current urban temperatures, while the future urban temperatures are unprecedented in London. On the other hand, the UHI-effect is almost the same in current and future conditions, and also the spatial pattern remains more or less unchanged, indicating that city districts more prone to urban heating in the present, are also expected to be more prone to heating in the future.

70.4 Conclusions

We have modelled and analysed the current and future urban climate in eight cities using the UrbClim model. By coupling the model to ERA-Interim reanalysis meteorological data, we identify city districts which are, at present, most prone to urban heating effects. The influence of global warming on the urban climate at the end of the current century (2081–2100) has been assessed by coupling the model to the output of 11 global climate models.

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Questions and Answers

Questioner: K.H. Schlünzen

Question: How is the bias correction done? How do you ensure it is physically consistent for e.g. temperature and humidity?

Answer: The bias correction between the runs with ERA-Interim data and the runs with GCM-data for the reference period is described in Lauwaet et al. (2015). Hence, we refer the questioner to this article for a detailed description of the procedure and its influence on the data. Since only the temperature results of the GCM-runs are used, the bias correction only deals with the temperatures.

Questioner: J. Plein

Question: Please describe the model. What are the driving factors of the UHI-effect?

Answer: The model is described in De Ridder et al. (2015). Hence, we refer the questioner to this article full a detailed description. The main driving factor of the UHI-effect during the late afternoon and the evening is the release of heat that has been stored in the buildings and artificial structures in the city.

Questioner: D.G. Steyn

Question: What effect will changes in the UHI have on air quality?

Answer: There are numerous studies that focussed on the close link between air quality and climate change. Most of these studies, however, do not specifically look at the effects of urban climate. We think that the change in (urban) temperatures has a limited influence on air quality, but also that other elements of urban climate, like a reduced wind speed, have larger influences.

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