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Future climate of Brussels and Paris for the 2050s under the A1B scenario

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ABSTRACT

Within the framework of the ACCEPTED project (an Assessment of Changing Conditions, Environmental Policies, Time-activities, Exposure and Disease), a high-resolution urban dynamical downscaling technique has been applied for the cities of Paris and Brussels. This paper focuses on the first part of the ACCEPTED project where simulations of present and future urban climate over Brussels Capital Region and Grand Paris Region are conducted. The downscaling strategy was first evaluated for a 10-year period [2001–2010] using ERA-INTERIM re-analysis data. In a next step, a downscaling simulation for 10-year period 2046–2055 under the IPCC SRES A1B scenario was performed. Results from our simulations indicate that while both cities warm substantially for the 2050s horizon (1.6 °C and 1.8 °C for Brussels and Paris respectively), climate change will have a neutral impact on annual mean urban heat island (UHI) intensity. The largest and statistically significant change of nocturnal (daytime) UHI is noted during winter (summer) season with an increase (decrease) of +0.2 °C (−0.1 °C) for both cities. During summer, the decrease in daytime UHI is directly connected to soil drying over rural areas, while the increase in nocturnal UHI during the winter can be explained by the projected decrease of wind speed.

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1. Introduction

As a result of intense worldwide urbanization, 50.5% of the global population lived in cities in 2010 (UN-Habitat, 2010) and this proportion will continue to grow in the future. By 2050, according to the latest UN-Habitat scenario, it is projected that 70% of the worldwide population will be urban residents. Cities affect the local weather by perturbing the wind, temperature, moisture, turbulence, and surface energy budget field. One very known phenomenon is the so-called urban heat island (UHI) effect where urban air temperatures are substantially higher than corresponding temperatures in the surrounding rural areas. The climate in urban areas is among the most important priorities of the impacts of climate change. Heat waves in the past have demonstrated that urban areas are vulnerable to decreased thermal comfort and air pollution episodes (Semenza et al., 1999). For example in 2003, about 35,000 people died because of a heat wave in Western Europe (Bhattacharya, 2003; Rosenzweig et al., 2010).

To maintain or even improve the quality of living in cities, urban planners need detailed information on future urban climate. However, such information is provided only to a limited degree by the recent studies using Global Circulation Models (GCMs) (McCarthy et al., 2010; Oleson et al., 2011; Oleson, 2012). In fact, due to the coarse horizontal resolution of GCMs and since urban surfaces (cities, towns and settlements) cover less than one percent of the world's land area (Schneider et al., 2010), climate change signals projected by GCMs may not capture certain mesoscale features of the urban heat island. For example, UHI can induce thermodynamically driven regional-scale flows (i.e. the urban heat island circulation).

Regional Climate Models (RCMs) are widely used to understand meso-scale processes as well as to downscale climate change projections to the regional scale required for urban impact studies. McCarthy et al. (2012) used the latest version of the Hadley Centre Regional Climate model HadRM3 at 25 km resolution coupled to a simple urban land-surface scheme (Best et al., 2006) to assess the sensitivity of UK urban climates to large-scale greenhouse gas induced climate change, local forcing from urban land use, and anthropogenic heat flux resulting from energy use in urban areas. The results show that greenhouse gas induced climate change is similar over both urban and rural land surfaces suggesting that under a changing climate the relative magnitude of UHIs in the UK would remain the same. Kusaka et al. (2012a, 2012b) and Adachi et al. (2012) used the Weather Research and Forecast (WRF) model with a 3 km grid increment coupled to an urban canopy model to study the projected urban climate for the August months of the 2070s, under the SRES A1B scenario, in the three largest urban areas in Japan: Tokyo, Osaka, and Nayoga. Using a pseudo global warming method and thus keeping the current climate CO_2 concentration unchanged throughout the simulation, the results show that the daily mean and diurnal variation of UHI in the future is almost identical to those of the present climate. More recently, Argüeso et al. (2014) used the WRF model with 2 km spatial resolution to examine the impact of future urban expansion on local near-surface temperatures for Sydney (Australia) using a future climate scenario (A2). Other urban climate projections generally employ a dynamical downscaling of global climate model information with a regional climate model, while further high-resolution simulations are often performed using some type of statistical downscaling approach (e.g. Früh et al., 2011). Alternatively, the regionally downscaled model output is used to force an offline land surface scheme (e.g. Town Energy Balance, Masson, 2000) with a resolution of 1 km (Lemonsu et al., 2013). However, because of the offline mode of these simulations, the urban heat island signature is not included in the atmospheric forcing. Thus, the contribution and feedback processes induced by urban heat island and climate change are not taken into account when increasing the horizontal resolution. Recently, Hamdi et al. (2014a) developed a new method to dynamically downscale a climate change scenario at the city level. First, the regional climate simulations were performed with a new version of the limited-area model of the ARPEGE-IFS system running at 4 km resolution called ALARO (Gerard et al., 2009; Hamdi et al., 2012a, 2012b, 2014a; De Troch et al., 2013) coupled with the Town Energy Balance scheme (TEB). Then, in order to further downscale the regional climate projections to an urban scale, at 1 km resolution, a standalone surface scheme was employed in offline mode using the forcing coming from the lowest model level of the 4 km regional climate simulations. The study by Hamdi et al. (2014a) demonstrated that