A GIS-BASED DECISION SUPPORT TOOL FOR URBAN CLIMATE RISK ANALYSIS AND EXPLORATION OF ADAPTATION OPTIONS, WITH RESPECT TO URBAN THERMAL ENVIRONMENTS

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Abstract

Changes to UK policy mean that some local authorities (LAs) are now required to demonstrate an adaptive response to current and future climate impacts, in order to manage risks to service delivery, the public, local communities, local infrastructure, businesses and the natural environment, and to make the most of new opportunities (e.g. National Indicator 188). In order for this to be achieved successfully it is essential that the LAs have access to knowledge and data about how climate changes are likely to impact their region, and that these data are communicated effectively to planners, designers and infrastructure owners. A GIS-based decision support tool is being developed to facilitate this process and has been designed specifically to allow the user to explore future heat scenarios and vulnerability to the thermal environment. The tool will synthesise temperature data from heat emission estimates, *in situ* measurements, remote sensing, the HadRM3 regional climate model and the Climate Research Unit weather generator to provide the user with high spatial resolution visualisations and data associated with the current and future thermal environment in a particular area. Future development of the tool will involve the integration of mesoscale model and building simulation outputs, which will be used to examine adaptation options, such as the integration of green infrastructure. This will enable the user to evaluate urban adaptation strategies related to heat and thermal comfort, according to heat, energy and emissions criteria.

Key words: GIS, climate, adaptation

1. INTRODUCTION

Extreme and/or prolonged high temperatures are increasingly being recognised as posing a serious climate hazard due to the severe consequences of several recent heat wave events (Gosling et al, 2009). Urban areas in particular are more vulnerable to these effects due to the presence of the urban heat island. Furthermore, projected temperature rises, together with the tendency toward urbanisation suggest that the urban thermal environment is likely to become increasingly uncomfortable in the future. This has direct consequences for the urban population and infrastructure. For example, in the UK building thermal design standards specify that the internal resultant dry temperature should not exceed 28°C for more than 1% of the occupied time, in order to maintain a comfortable environment (CIBSE, 2006). However, it has been suggested that this will be increasingly difficult to achieve, under future climate scenarios, from 2050 onwards (Levermore et al, 2004). Given the long lifetime and low turnover rates of building stock, and the additional warming influence of the urban heat island effect, some degree of adaptation is necessary to avoid internal overheating.

The internal thermal environment to which people are exposed is an important factor, amongst others, for ascertaining risk of heat stress, the implications for work productivity and the possibility of heat-related mortality for city dwellers. This is further compounded in urban areas by the limited access to cooler external temperatures and the lack of respite from higher temperatures during the night time. Several studies have highlighted the potential shift in annual mortality patterns which may arise from changing climatic conditions and the fact that these trends will be felt most acutely in urban areas (McGeehin and Mirabelli, 2001; Gosling et al, 2009).

As a result of the growing body of evidence which points to the potential public health implications, disruption to services and damage to infrastructure associated with the changing urban environment, governing bodies, service providers, infrastructure owners and other key stakeholders are being encouraged to develop sustainable communities by implementing appropriate adaptive strategies (Department for Communities and Local Government, 2007). These responses to current and future climate impacts are designed to not only manage climate-related risks to service delivery, the public, local communities, local infrastructure, businesses and the natural environment, but also to make the most of new opportunities.

In order for adaptation strategies to be implemented successfully it is essential that decision makers have access to the relevant knowledge and data about climate risks to their region, and that these data are communicated effectively. The current work describes the development of a GIS-based decision support tool which has been

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designed to facilitate the adaptation process by allowing the user to explore future heat scenarios and vulnerability to the thermal environment. The user is also able to evaluate a range of adaptation options according to temperature, greenhouse gas emissions and heat emissions across differing spatial scales.

2. CHARACTERISTICS OF THE DECISION SUPPORT TOOL

The decision support tool has been developed using the case study area of Greater Manchester, UK. However, the data and methodology used could be tailored to other conurbations in the future, while the present outputs can provide a useful analogy for other northern European cities.

The tool is designed to be used progressively with respect to a downscaling of the spatial scale: from city through to neighbourhood and eventually individual buildings. The decision support tool is embedded within a GIS framework. This allows for greater flexibility of the user interface when working across the different spatial scales and can provide useful visual data presentation. GIS is also already widely used within local authorities which means users of the tool are already familiar with the software, and that the data and outputs produced by the tool will be compatible with their existing datasets.

Discussions with key stakeholders throughout the development process have ensured that the tool provides the functionality, detail and level of information required by the end-users. In light of these discussions, the tool has the capacity to:

1. Inform about current day hazard, vulnerability and risk
2. Inform about future hazard, vulnerability and risk
3. Allow 1 and 2 to be specified at city, neighbourhood and building scales and explored using a search function
4. Allow adaptation to be considered, with respect to the implications for temperature, greenhouse gas and heat emissions, at city, neighbourhood and building scales
5. Allow inputs, such as a percentage change in surface cover properties, to be modified according to user requirements
6. Allow reports and/or maps to be generated

3. DATA AND METHODS

3.1. Current and Future Temperature Patterns

The heat-related hazard data are derived from a variety of sources, which have been combined to provide a robust, fine-scale representation of current and future spatial temperature patterns across the conurbation. A suite of regional climate model baseline and future timeslice simulations were produced using the Hadley Centre Regional Climate Model (HadRM3). The 25 km resolution output from the HadRM3 regional climate model was subsequently downscaled to 5 km resolution using a stochastic weather generator (Kilsby et al, 2007). The 5 km gridded temperatures provide the basis for the city-scale hazard data (Figure 1).

To refine the data to neighbourhood-scale (~1-3 km^2) resolution, temperature data were collected using airborne and ground-based transects. The airborne transects recorded surface temperatures averaged over a 40-50 m footprint. The ground-based transects recorded near surface air temperature at a 5 s sampling interval (~100m). The results of the *in situ* thermal mapping work are described in more detail in Smith et al (2009). These data provided the basis for an empirical model which includes the variables distance from an urban centre, surface cover and building density as input parameters (Smith et al, 2009). The model is scalable up to 200 m grid square resolution, which allows temperature patterns to be outputted at the finer spatial scale required by end-users of the tool (Figure 1).

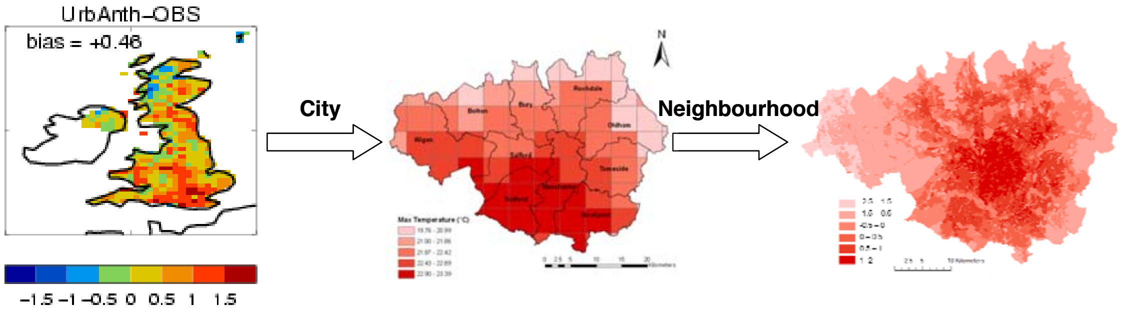

Figure 1: Process of downscaling temperature patterns using HadRM3, a stochastic weather generator and an empirical model.

3.2. Vulnerability and Exposure to Hazard

Climate-related vulnerability within the decision-support tool is separated into socio-economic vulnerability and building vulnerability. The former is established using Census data and is a function of population age, health and well-being. The latter is related to the built form. Buildings across the conurbation have been classified according to their density, height, age, use, orientation, and proximity to greenspace, which together provide an indication of a buildings vulnerability to high temperatures.

Combining the spatial hazard data and the vulnerability data provides the temperature-related risk across the region.

3.3. Adaptation Strategies

Once the climate risk has been established, the tool allows a user to explore a variety of adaptation mechanisms which are designed to alleviate the risk of thermal discomfort. The adaptation strategies include modifications at an individual building-scale, but there also options to consider adaptative modifications that take into consideration the buildings local context and the surrounding area. The pre-defined adaptation options which are available to end users of the tool are summarized in the table below. Each adaptation option is specified according to whether it is suitable for existing developments, new developments or both.

ADAPTATION OPTION	NEW DEVELOPMENT	EXISTING DEVELOPMENT
CITY-SCALE		
Workplace Scenarios		
Greater number of people working at home	✓	✓
NEIGHBOURHOOD-SCALE		
Development Layout		
Orientation	✓	
Solar access/shading design	✓	✓
Integration of green/blue space (e.	✓	✓
BUILDING-SCALE		
Improvements to the Building Envelope		
Increasing thermal mass	✓	✓
Implementation of green roofs	✓	✓
Improving passive ventilation	✓	✓
Reducing Solar Gains		
Positioning of the glazing.	✓	
Reducing the glazing percentage.	✓	
Implementing improved glazing types	✓	✓
Use of shading	✓	✓
HVAC System		
Low-energy, mixed mode mechanical ventilation design,	✓	
Integration of renewable energy systems and CCHP.	✓	
Natural ventilation	✓	

Table 1: Pre-defined adaptation options which are available as part of the decision-support tool.

When the different adaptation options are explored within the tool, the user is provided with a report summarising what the impacts of implementing the strategy will have upon local temperatures, greenhouse gas emissions and direct heat emissions. This information can then be used to aid the decision-making process. The tool does not allow on the fly processing so these summary data have been pre-calculated using a meso-scale climate model, heat and greenhouse gas emission inventories and building simulations using DesignBuilder software.

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