High resolution thermal stress mapping in Africa: decision maps for urban planning in Johannesburg

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Abstract

Urban planning will benefit from tools that can assess the vulnerability to thermal stress in urban dense cities. Detailed quick-scan heat stress maps, as developed in this study for Johannesburg, South Africa, have proven valuable in the decision-making process on this topic. It raised awareness on the urgent need to implement measures to tackle the effects of climate change and urbanisation. Awareness on heat stress has led to the implementation of measures to mitigate the effects of climate change. As in other countries, nature-based solutions (e.g. green roofs and walls, swales, rain gardens, planting trees etc.) are considered in urban areas in South Africa for various reasons. The awareness of the effect of nature-based solutions on heat stress is still low, which can be improved by the use, understanding and importance of heat stress maps. Some of these measures are already mapped on the open source web tool, Climate-scan (www.climatescan.nl) for international knowledge exchange around the globe.

Keywords: *Heat stress, Modelling, Urban Planning, Thermal stress*

Introduction

Thermal stress has become a key issue for many cities around the world. Densely-populated urban landscapes with concomitant infrastructure (asphalt, concrete, brick, metal) soak up heat from sunlight. This energy absorption leads to "*urban heat islands*", where cities experience higher-than-normal heat temperatures, as compared to surrounding areas. Urban areas throughout the world are exposed to heat stress and the resultant effects on infrastructure, livelihood, health etc. With the continuing impacts of climate change, thermal stress - already experienced in dense urban areas - will become more acute and will lead to serious problems such as indicated in the mindmap (**Figure 1**), which is used in the Netherlands to discuss and explain urban heat issues. Therefore, urban planning departments are in need of tools that can assess the vulnerability to thermal stress so that they can plan the implementation of measures to reduce heat stress, such as nature based-solutions (green roofs and walls, planting trees,

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swales, rain gardens etc.). In Johannesburg and other urban areas in South Africa, tree planting programmes by municipalities, sponsored by corporates or implemented by the communities themselves helps alleviate related heat stress issues, and improves air quality and liveability. This is also necessary to compensate for poor spatial and town planning in the apartheid-area (Kings, 2016).

In addition, the maps will assist in making stakeholders and role players, such as property developers and urban planners, aware of heat stress effects. Quick scan climate models can visualise priority areas to address several challenges in urban dense areas, such as flooding, drought etc. (Boogaard et al., 2017). Quick scan detailed heat stress models are relatively new and are under development to provide urban planners with detailed insights into the heat stress effect in cities at a street, or even object level.

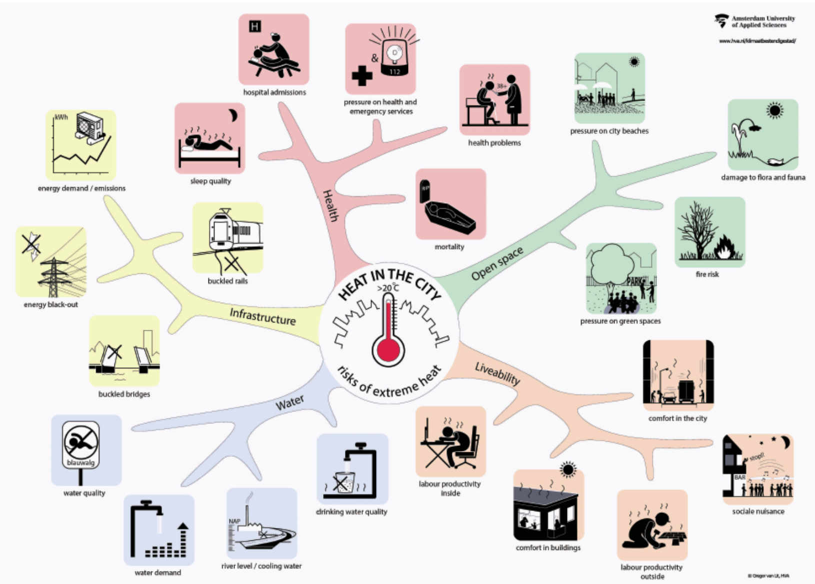

Figure 1. Map of City level heat stress effects (Source: Klok and Kluck, 2016)

Objectives

Heat stress maps are currently not applied in South Africa. The objective of this research is the development of a detailed geographic information system (GIS)-based thermal stress map for cities like Johannesburg. While maps on flooding, drought, land subsidence (resulting in damage to infrastructure) are widely used, maps indicating heat stress in cities are relatively new for target user groups, such as urban planners, to assess the resilience and well-being of cities with these high resolution decision maps for urban planning.

Method

The quick-scan GIS-based thermal stress map of Johannesburg was developed in order to give quick insight into the possible thermal stress locations in a part of the city. It is based on an accurate Digital Elevation Model in which physical processes are modelled in detail for a limited area. For a quick insight into thermal stress on a larger scale, to limit computation times, some rough simplifications of the actual physical processes can be made (Boogaard et al., 2016). Those simplifications imply that the (relative) increase in air temperature is a summation of local effects, like presence of buildings, trees, greenery and water (Kluck et al., 2015). The maps present the Physiological Equivalent Temperature (PET) at the hottest hour of an almost windless day and are presented relative to the rural temperature of a meadow. The PET is calculated from the local estimation for air temperature, wind, and humidity. The choice for the hottest time of a windless day means that the direct radiation has a major influence on the PET (much more than air temperature, wind and humidity).

To make a detailed heat stress map, topographical data with detailed information on materials, roads, waterways and dataset inclusive of the height of all infrastructure and trees (to model shadow effect) is needed. Combining the elevation model, the dataset with buildings and aerial photographs, a model of the city is constructed to get a better overview of the outcomes of the model. The maps give a detailed estimate of the maximum PET during a heat wave, as a measure of thermal comfort.

Findings

The heat stress map and topographic map of Johannesburg (**Figure 2**) developed for this study indicates hot areas in red ('much warmer') to purple ('very much warmer'), where high PET (thermal comfort) values can be expected, as in other pilot cases around the world. Purple areas are generally open spaces with hardly any shadow and greenery. The thermal maps for the African, Dutch and Asian cases are used to compare the differences in simulation results between different climates zones.

Figure 2. Heat stress map for Johannesburg (Source: Authors own)

Corresponding to the legend, the darker areas in **Figure 2** indicate areas where heat stress or thermal discomfort will be most experienced, and measures to mitigate these high temperatures will be advised. Measures that provide shading (trees or fabric) or minimise paving (replacing stones or tarred areas by greenery, lawns etc.) are mostly implemented to lower temperatures in the urban dense area.

Conclusion

The heat stress maps are intended for use by urban planners and other stakeholders and decision makers to assess the resilience and well-being of cities. With previous climate modelling around the globe, the end result is an international comparison of the potential use of heat stress maps under different climates in Europe, Asia and Africa. These maps are ideal quick-scan tools for urban planners who, in combination with other tools, can use it to improve planning. The heat stress maps are clearly related to land and water cover, which gives an argument for urban planners for implementing green and blue measures from the perspective of mitigation of heat stress – and adaptation to health impacts due to climate change. As in other cities, in the city selected for this study, Johannesburg, such mapping tools have proven valuable in the decision-making process and it is envisaged that they will have similar successes in other cities the world over. In Europe and Asia, these maps have been an important input for master classes on climate adaptation in The Netherlands and Taiwan. It raised awareness on the need to implement measures to tackle heat stress and has led to consideration of implementation of various sustainable urban drainage systems in The Netherlands (Kluck et al., 2018).

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