Spatial modeling of heat stress risk in Berlin

Andrea Philips
Humboldt University Berlin
Geoinformation Science Lab
Unter den Linden 6
10099 Berlin, Germany
andrea.philips@geo.hu-berlin.de

Christian Schuster
Humboldt University Berlin
Geoinformation Science Lab
Unter den Linden 6
10099 Berlin, Germany
christian.schuster@hu-berlin.de

Tobia Lakes
Humboldt University Berlin
Geoinformation Science Lab
Unter den Linden 6
10099 Berlin, Germany
tobia.lakes@geo.hu-berlin.de

Abstract

Heat waves threaten urban populations as heat stress is often linked to mortality, morbidity and a decline in the quality of life. Because heat stress vulnerability and risk are difficult to conceive, we need to understand the spatial patterns and relationships of these phenomena, and understand how multiscale and multidimensional vulnerability and risk can be spatially modeled. As previous researches have not sufficiently integrated both spatially explicit models and individual level studies, we analyze and model heat stress vulnerability and risk using a regression analysis for predictor determination, qualitative interviews on an individual basis and integrate the gathered information into a Bayesian Network model. Thus we aim to provide a suitable basis for planners to develop adequate coping strategies in urban areas.
Keywords: Heat stress risk, urban vulnerability, spatial modeling, Bayesian Network modeling, qualitative interviews, regression analysis

1 Introduction

There has been a great deal of research in recent years on the impact of climate and weather on health. In particular, urban heat stress has been linked to mortality, morbidity and a decline in the quality of life [6, 8]. Reducing vulnerability and increasing resilience to urban heat stress are key elements for adapting to present and future climate impacts [9, 12, 14]. Among the various vulnerability concepts developed in recent years [5, 11], vulnerability within climate change research describes a given system's susceptibility to suffer harm from the impacts of a hazardous event. The concept of risk then combines the vulnerability with the magnitude of the impact of a hazard and the probability of its occurrence. Closely linked is the evolving concept of resilience that can be referred to as the ability of an urban system to withstand shocks and stresses, such as heat stress [12].

In recent empirical studies on vulnerability and risk to urban heat stress one contrasts two approaches: First, spatially explicit analyses of vulnerability and risk that employ area-based vulnerability and exposure indicators like biophysical variables (surface temperature, amount of green) in combination with aggregated socio-economic datasets such as age or population density [13]. These analyses are often carried out using medium to small-scale datasets at a specific point of time [13]. Second, individual-level vulnerability and risk analyses that aim for a better understanding of underlying socio-economic influences on behavior-driven exposure and adaptation capacities [10]. These individual level analyses have gained insights into the temporal variation of climatic effects on individual health status [6].

However, [3] states that only few authors have addressed both spatially explicit models and individual level studies of vulnerability and risk to heat stress. Therefore, a major challenge lies in the multiscale spatial analysis and modeling of urban heat stress risk which is determined by vulnerability and hazard and which is described by multidimensional characteristics of the urban population.

Our study, which is part of the ongoing research program "Urban Climate and Heat Stress in mid-latitude cities in view of climate change" (UCaHS), therefore addresses the following questions:

1. What are the spatial patterns and underlying processes of heat stress vulnerability and heat stress risk in an urban area?

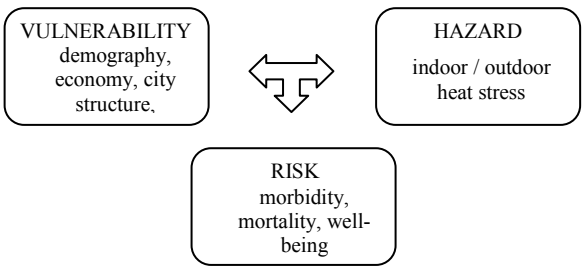
2. How can multiscale and multidimensional vulnerability and risk to urban heat stress be spatially modeled?

2 Methods

2.1 Conceptual model and regression analysis

Based on the *pressure-and-release* (PAR) model by [2] and its assumption that *risk = vulnerability * hazard*, we generated a conceptual framework for our study (Figure 1).

Figure 1: The three dimensions of the multiscale and multidimensional risk model of urban heat stress.



Source: Own figure.

To investigate predictors of urban heat stress risk a regression analysis is performed. On a sub-district administrative level ("Lebensweltlich-orientierte Räume") mortality as dependent variable to reflect heat stress is analyzed. Different sets of spatially explicit model drivers could be found and interpreted, that finally show how biophysical as well as socio-economic factors influence urban heat stress.

2.2 Qualitative interviews

Interviews with selected vulnerable groups will be conducted to gain insights into the (self-) perception of vulnerability and potential adaptation strategies in a later stage of the project.

2.3 Spatially explicit Bayesian Network model

Due to their ability to exploit complex datasets and especially to explicitly consider uncertainty and to be iteratively updated with new knowledge, Bayesian Networks (BN) have gained increasing interest in health and ecological studies [1, 4, 7].

BN allow to link research findings by calculating conditional dependencies. Socio-economic and biophysical variables are illustrated as nodes that influence the target variable mortality or heat stress risk, respectively, by modifying the probability of its occurrence. BN are capable of integrating different data types including qualitative data gained from interviews.

Moreover, BN allow us to discover unknown relationships and feedback mechanisms within the data and allow the integration of expert knowledge about variables to model vulnerability and risk to heat stress.

3 Preliminary results

The first results of the regression analysis show significant socio-economic and biophysical predictors for urban heat stress. Their spatial distribution furthermore suggests areas in Berlin where interviews with subsequently selected vulnerable groups can be carried out.

The expected outcome of this research is to further improve the methodology of spatial modeling. We expect new insights into patterns and processes of vulnerability and risk to urban heat stress by linking multiple dimensions from an individual to a city-wide analysis level. The resulting model may then allow us to develop scenarios that can be an important asset in adequately developing coping strategies in urban areas.

Acknowledgements

The study was funded by the Deutsche Forschungsgemeinschaft (DFG) as part of the DFG Research Unit 1736 "Urban Climate and Heat Stress in mid-latitude cities in view of climate change (UCaHS)" (grant nos. SCHE 750/8-1 "Scientific co-ordination of the Research Unit" and LA 2525/2-1 "Urban vulnerability").

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