DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
Chalmers University of Technology, school year 2021-2022

Urban heat island and outdoor thermal comfort

Background

Urban environments are characterized by hard, dark-colored surfaces which, through a heat-absorbing and radiant effect, result in higher outdoor temperatures and less wind. This phenomenon is called urban heat island (UHI) and indicates reduced cooling effects. This is why it feels warmer to be outside in a city than in a rural area during summer.

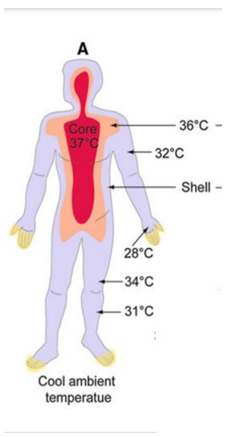
UHI is a time dependent phenomenon. The thermal mass of hard surfaces is large, leading to distinct time delays between the maximum sun intensity and highest temperatures. Available simulation tools for thermal comfort in urban outdoor environments are limited in this regard, showing merely stationary situations. Building physics simulation tools can be of help here. The established modelling techniques for operative temperature in indoor environments can be used for outdoor environments. The challenge is to keep the simulation time at a reasonable level while providing useful results. This can be achieved by combining numerical simulations with other, much faster calculation techniques such as response function methods. Another challenge is to show that we experience different operative temperatures at different parts of our bodies (top of head, chest, back, left/right arm, etc) when, for example, sitting outdoors.

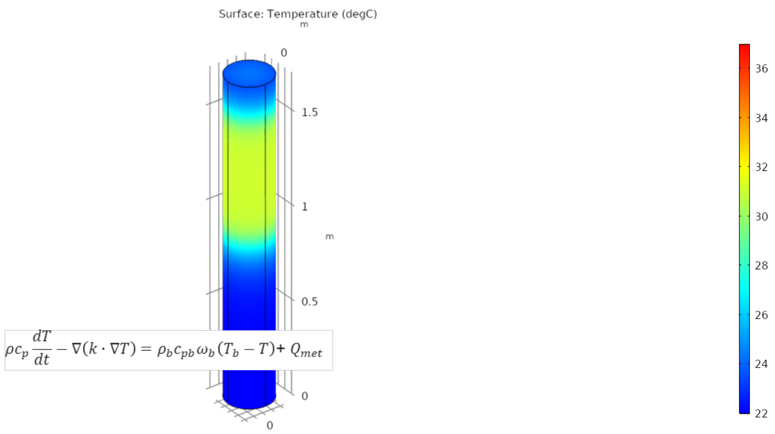
Aim

This project aims at developing a method for fast and accurate simulations of UHI effects, and of perceived outdoor thermal temperature under UHI conditions. The project is at the interface between different fields, ranging from building physics to fluid dynamics and heat transfer and advanced numerical models and it is a collaboration between the departments of Architecture and Civil Engineer and Mechanics and Maritime Sciences.

Methods

The transient heat storage in hard outdoor surfaces is to be approached by combining analytical and numerical calculation methods commonly used in building physics. Response function method (RFM) is seen as a promising analytical technique. The approach is based on the so-called Penne's equation, a convective-diffusion heat transfer equation applied in the field of bioheat transfer in the human body. The applications of the equations range from medical usages to the design of spacesuits for astronauts. Because RFM is not included in regular courses in building physics/heat transfer, students will get help in learning and mastering the method. Implementation of RFM can be done in i.e. Matlab, MathCad, Python, etc. Numerical simulation in Comsol will be used for benchmarking of RFM, and for detailed calculations of perceived outdoor temperature. For the latter, a 3D model of a human body with realistic thermal properties will be used. Furthermore, a simplified model of an urban environment will be used as a case study. Inspiration will be found in existing urban areas in Gothenburg simulated using Computational Fluid Dynamics (CFD). Finally, a literature review of UHI effects and models for operative temperature will be needed to gain insight in state-of-the-art modelling techniques.





Required qualifications

Knowledge about transient heat transfer and storage in building materials or other spaces with distinct thermal inertia, and of operative temperature. Interest for and skills in modeling and simulations in Comsol, Matlab/Python and CFD. Related master's programs are MPSEB, MPSES and MPAME.

Relation to research

The thesis will contribute to an ongoing research project on "UEQ - simulations, visualizations and evaluations of future sustainable urban environments".

Number of students

1-2

Supervisor and examiner

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