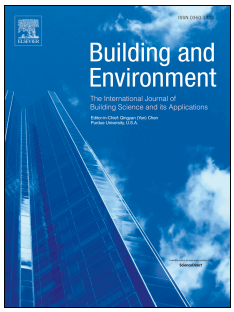
Accepted Manuscript



System dynamics of human body thermal regulation in outdoor environments

Valentin Melnikov, Valeria V. Krzhizhanovskaya, Michael H. Lees, Peter M.A. Sloot

PII: S0360-1323(18)30432-3

DOI: 10.1016/j.buildenv.2018.07.024

Reference: BAE 5584

To appear in: *Building and Environment*

Received Date: 1 May 2018

Revised Date: 2 July 2018

Accepted Date: 16 July 2018

Please cite this article as: Melnikov V, Krzhizhanovskaya VV, Lees MH, Sloot PMA, System dynamics of human body thermal regulation in outdoor environments, *Building and Environment* (2018), doi: 10.1016/j.buildenv.2018.07.024.

System dynamics of human body thermal regulation in outdoor environments

Valentin Melnikov[a,b,1,*], Valeria V. Krzhizhanovskaya[c,d,1], Michael H. Lees[c,d,1], Peter M. A. Sloot[a,c,d,1]

[a] *Complexity Institute, Nanyang Technological University, 61 Nanyang Drive, 637335, Singapore*
[b] *Future Cities Laboratory, Singapore-ETH Centre, Singapore*
[c] *ITMO University, Saint Petersburg, Russia*
[d] *University of Amsterdam, the Netherlands*

Abstract

Thermal comfort of people in outdoor urban spaces is a growing concern in cities due to climate change and urbanization. In outdoor settings the climate and behavior of people are more dynamic than in indoor situations, therefore a steady state of the thermoregulatory system is rarely reached. Understanding the dynamics of outdoor thermal comfort requires accurate predictive models. In this paper we extend a classical two-node model of human body thermal regulation. We give a detailed description and interpretation of all the components and parameter values and test the dynamics of the model against experimental data. We propose a modification of the skin blood flow model which, while keeping realistic values and responsiveness, improves skin temperature prediction nearly fourfold. We further analyze the sensitivity of the model with respect to climatic and personal parameters. This analysis reveals the relative importance of, for instance, air temperature, wind speed and clothing, in thermoregulatory processes of the human body in various climatic settings. We conclude, that our model realistically reproduces the dynamics of aggregate measures of human body thermal regulation. Validated for cool, warm and hot environments, the model is shown to be accurate in terms of its dynamics and it is conceptually and computationally far more efficient than any existing multi-node and multi-part model.

Keywords: human body thermal regulation, system dynamics, outdoor thermal comfort

1. Introduction

Thermal comfort of people in outdoor urban spaces is a growing issue for many of the world's cities due to the global processes of climate change and urbanization. Heat is not only related to physiological and psychological stress, but also to population morbidity and mortality [1]. The physiological thermal regulation system is one of the key means of adaptation of human beings to heat in outdoor environments. The state of this system, typically described with parameters such as core-, skin- temperature or sweating rate, defines stress and to a large extent determines

*corresponding author
Email addresses: mail@valmelnikov.ru (Valentin Melnikov), v.krzhizhanovskaya@uva.nl (Valeria V. Krzhizhanovskaya), m.h.lees@uva.nl (Michael H. Lees), p.m.a.sloot@uva.nl (Peter M. A. Sloot)
[1] Declarations of interest: none.