Human Heat Stress: Major Health Issue of Global Warming

Jiahao Han[1], James Kasting[2]

[1]Department of Physics, Dickinson College

[2]Department of Geosciences, Penn State University

Introduction

The normal range of a person's internal body temperature is 36.3 – 37.1°C[1]. A person's skin temperature, T_{sk}, needs to remain ~2 degrees lower than his core temperature in order for the metabolic heat to be transported out by the process of sweating and evaporation, thus giving T_{sk} < 35°C. Evaporative heat loss can only occur when the ambient wet bulb temperature, Tw, is less than Tsk, i.e. < 35°C. However, this is a 'best' scenario where the person is at rest, in shade, and with a gentle breeze. In addition, the health condition of the person is also ignored. We want to make a computer model to take these factors in consideration and make the situation more realistic, to see how these factors could affect the threshold of heat stress. We also developed a time-dependent model to see how fast a person would reach heat stress under certain conditions.

Previous Model

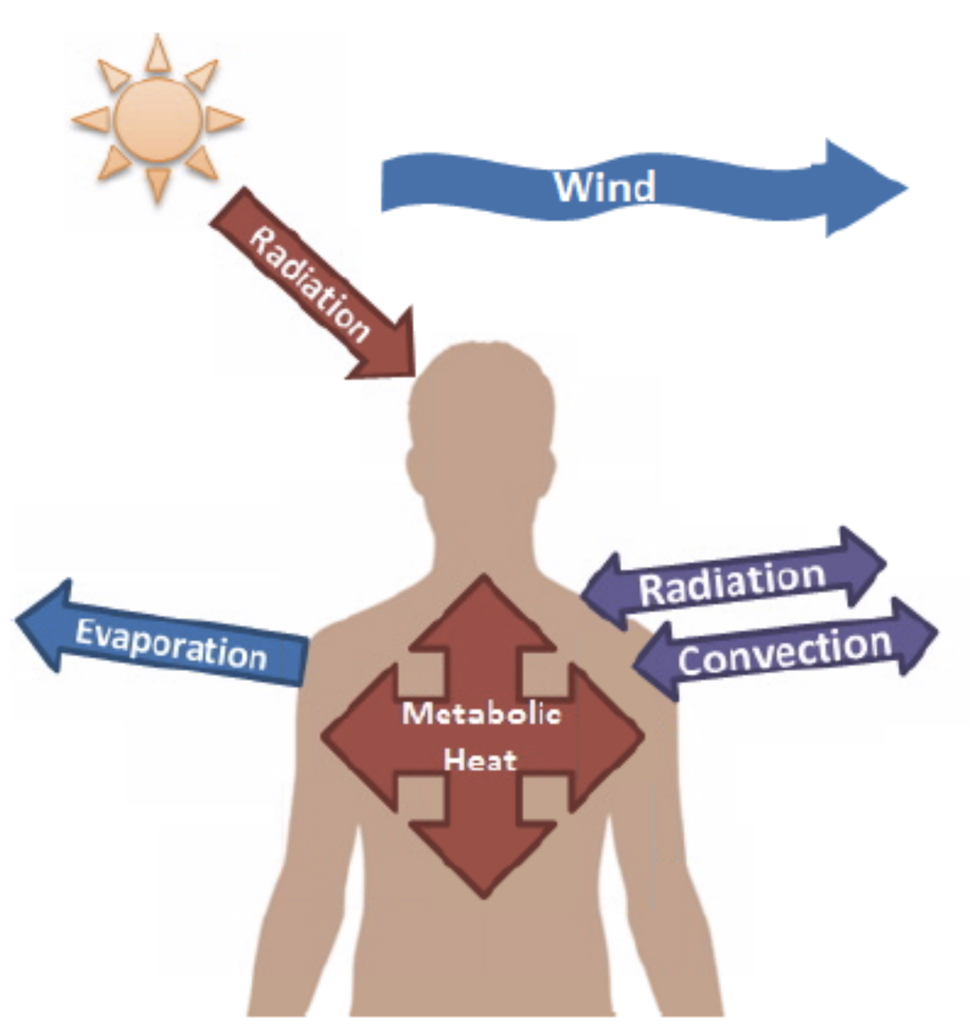

Figure 1[3]: Outline of model processes

Methods and Model

Time-dependent model

A new model was developed to see how long will a person reach heat stress at certain conditions. In steady state, the power absorbed and released by the body must be equal. We can express this balance by two equations:

$$F_{sk} = [\beta(1-r)E_{sol} + E_{bb} + f_c - H - E_{sw} - P_{out}] * A = 0$$

$$F_c = E_{REE} - fc * A = 0$$

where β (= 0.25) is the assumed fractional area of skin exposed to sunlight, r (= 0) is the assumed reflectivity of the person's skin to visible light, f_c is the heat flux per unit area from the core to the skin, H is the sensible heat flux from the skin to the air, and A is the surface area of the body. To perform the time-dependent calculations, we rewrote the above equations in the form

$$\frac{dT_{sk}}{dt} = \frac{F_{sk}}{Cam} \qquad \frac{dT_c}{dt} = \frac{F_c}{C(1-a)m}$$

To simplify the problem, we assumed that α was constant and had a value of 0.1. We then time marched these equations using the reverse Euler method with a time step of 0.1 s. The calculation was continued until T_{sk} and T_c reached approximate steady state.

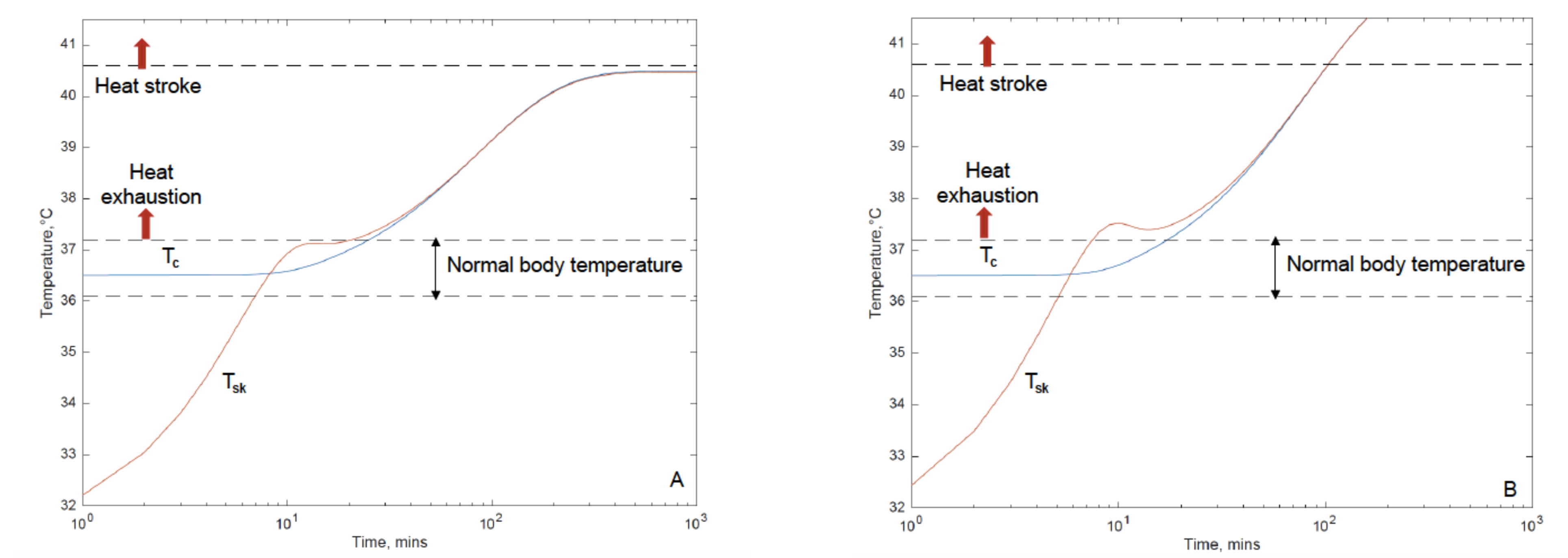

Figure 2. T_{sk} and T_c vs time (a) normal healthy person (b) obese

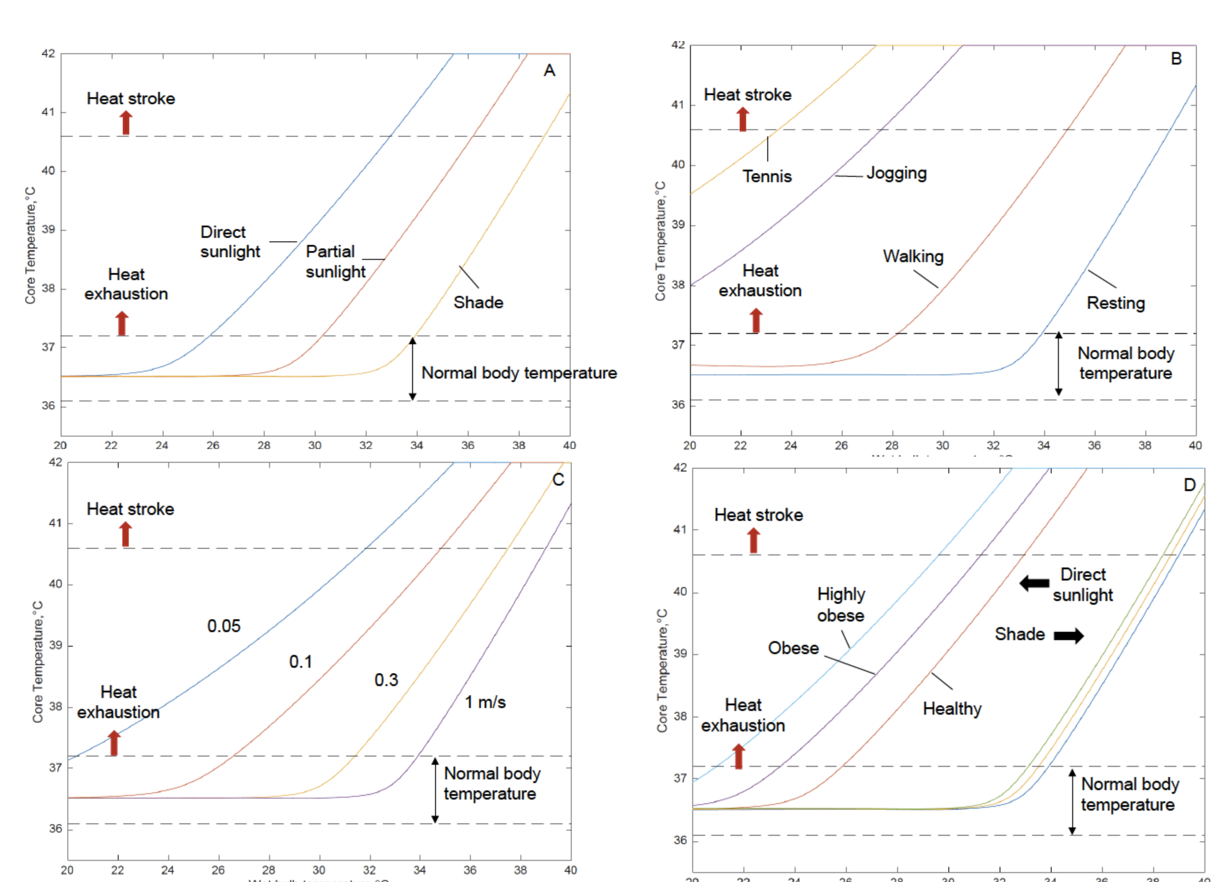

Figure 3. T_{core} vs T_{web} for various (a)solar radiations (b) physical activities (c) wind speeds (d) body sizes

Conclusions

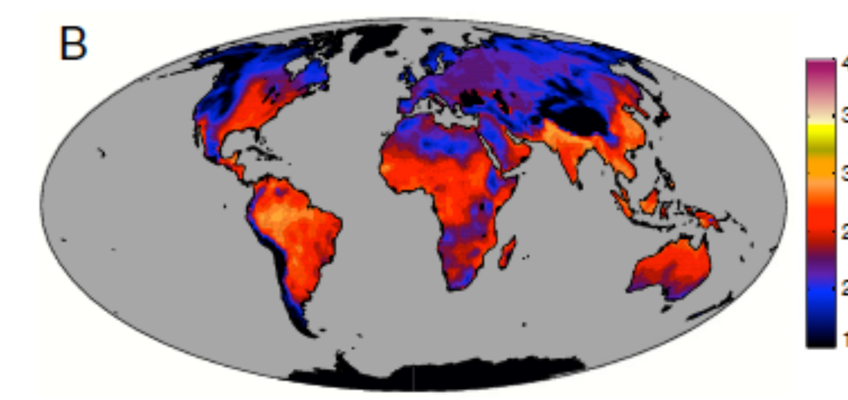

Figure 4[2]. Global wet bulb temperature

Human heat stress is already a major health issue in many parts of the world, India, Indonesia, and Southern China, and is becoming more serious as the climate warms. Maximum wet bulb temperatures today, as we can see from the figure, are typically less than 31°C, so it appears this lethal threshold is comfortably far off. However, the results shows that direct sunlight, physical activities, wind speed, and body size could all lower the lethal threshold by several degrees. All of this suggests that the threat of human heat stress is *not* far off in the future, but rather could start to be realized on a broad scale within the next few decades as global temperatures climb.

Reference

[1] J. L. Glazer, *American Family Physician* **71**, 2133 (Jun, 2005).
[2] S. C. Sherwood, M. Huber, *Proceedings of the National Academy of Sciences of the United States of America* **107**, 9552 (May, 2010).
[3] S. Foley, Development of a Computer Model of Human Heat Stress With Implications for Global Warming (May 2016)

Acknowledgement

Special thanks to Dr. James Kasting for great guidance on this project. I also want to thank Samuel Foley for previous work and willingness to share his model.

This work was supported by the National Science Foundation through the Network for Sustainable Climate Risk Management (SCRiM) under NSF cooperative agreement GEO-1240507.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.