Urban Climate–Human Coupling System: Model Development and Case Study

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Research Background and highlights

The compounding effect of global climate change and rapid urbanization exacerbates extreme heat events and poses severe threatens to pedestrians' thermal health in cities. To more realistically predict pedestrian-level urban heat stress, **we developed a cutting-edge urban environment-human interactive system UCM-HEATS.**

Highlights of UCM-HEATS:

1. Realistic radiative shading and trapping effect in street canyons
2. Dynamic human-environment interactions (dynamic human heat storage)

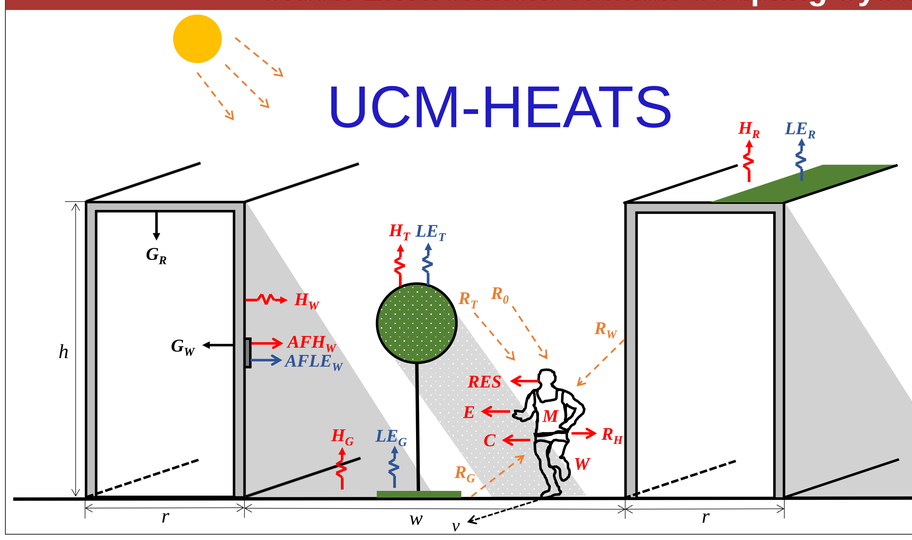
Applications of UCM-HEATS:

Impacts of urban environmental changes on pedestrian-level heat stress.

Impacts of human factors on pedestrian-level heat stress.

Our study can provide guidance on **urban heat mitigation strategies** with a nuanced consideration of various urban settings and different urban population.

Urban Environment-Human Coupling System



UCM parameters:
H: sensible heat flux
LE: latent heat flux
AFH: anthropogenic H
AFLE: anthropogenic LE

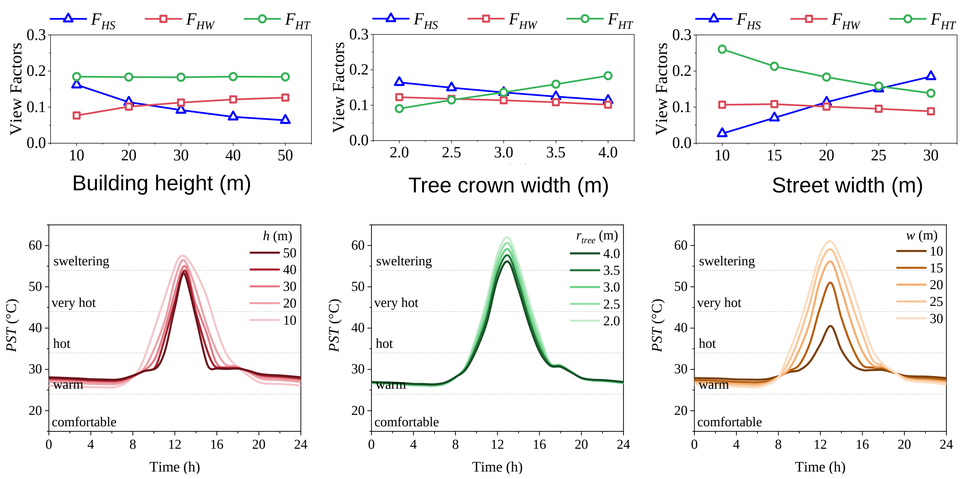
HEATS parameters:
R: Radiation
RES: Respiration
E: Evaporation
C: Convection
M: Metabolism
W: Mechanical work

Subscripts:
G: Ground, W: Wall, T: tree, 0: sun, H: human

Impacts of Urban Environmental Changes

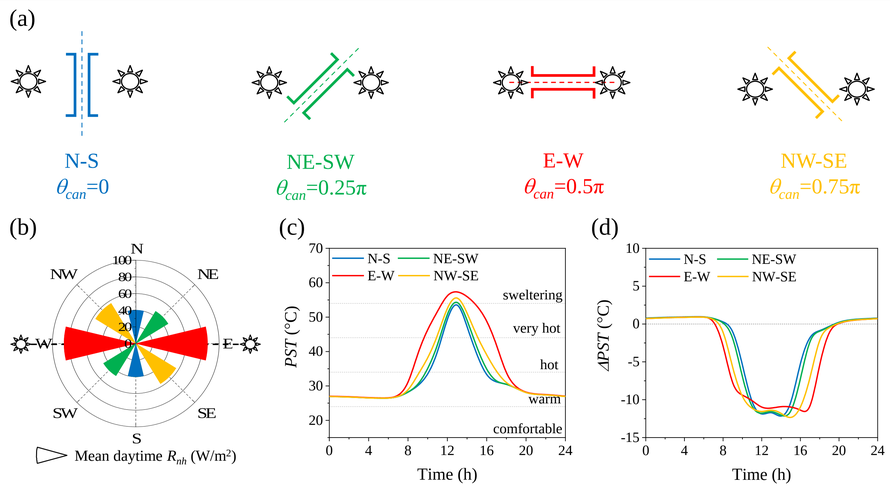
(1) Street canyon

- View factors (F_{HS}, F_{HW}, F_{HT}) are sensitive to street canyon and tree geometries.
- Radiative shading is effective to reduce human thermal stress, i.e. physiological subjective temperature (PST).



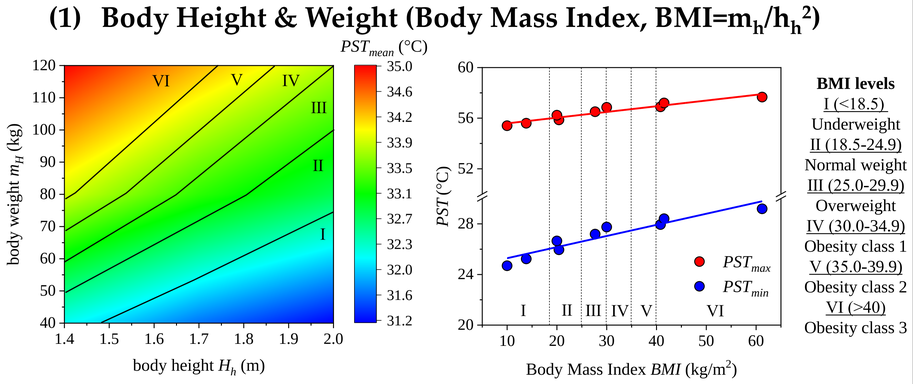
(2) Street Orientations

- Pedestrians receive more than twice daytime radiation on E-W streets than N-S streets.
- Trees show four more hours of effective shading in E-W streets compared with N-S streets.



Impacts of Human Factors

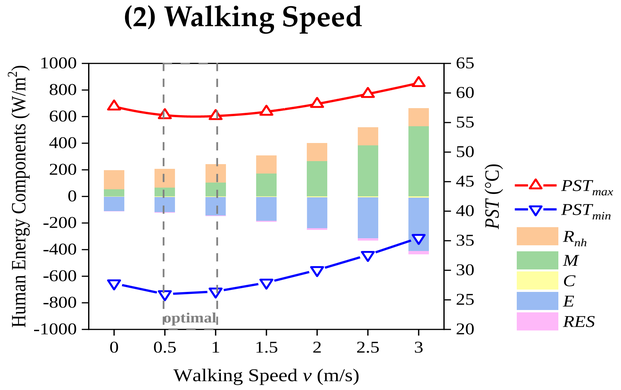
(1) Body Height & Weight (Body Mass Index, BMI=m_h/h_h^2)



BMI levels
I (<18.5) Underweight
II (18.5-24.9) Normal weight
III (25.0-29.9) Overweight
IV (30.0-34.9) Obesity class 1
V (35.0-39.9) Obesity class 2
VI (>40) Obesity class 3

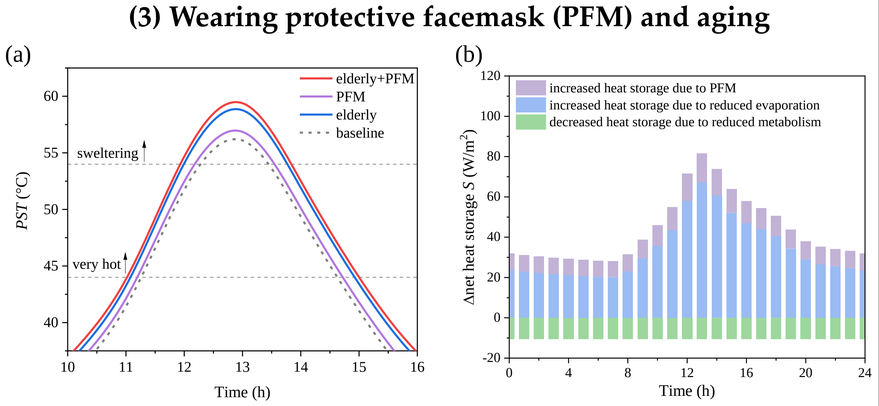
- A linear corelation between heat stress and BMI.
- An extra 2.3-4.5 C heat load in PST for obese pedestrians.

(2) Walking Speed



- Walking speed has a nonlinear effect on thermal comfort.
- Optimal walking speed is 0.5-1 m/s.

(3) Wearing protective facemask (PFM) and aging



- The elderly has weakened thermoregulation functions (e.g. less sweating)
- Protective facemasks (PFM) impede heat dissipation from faces.
- The elderly with PFM has more sweltering heat risks.

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References

[1] [UCM-HEATS] X. Huang, J. Song*, et al, Realistic prediction of pedestrian-level thermal stress in cities via a new urban environment-human coupling system, in preparation.
[2] [UCM] X. Huang, J. Song*, et al, The synergistic effect of urban heat and moisture islands in a compact high-rise city, Build. Environ. (2021) 108274. https://doi.org/10.1016/j.buildenv.2021.108274.
[3] [HEATS] D. Shi, J. Song*, et al, Dual challenges of heat wave and protective facemask-induced thermal stress in Hong Kong, Build. Environ. 206 (2021) 108317. https://doi.org/10.1016/j.buildenv.2021.108317.