

EFFECTS OF TREE PLANTINGS WITH VARYING STREET ASPECT RATIOS ON THE THERMAL ENVIRONMENT USING A MECHANISTIC URBAN CANOPY MODEL

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KEYWORDS: Pedestrian Thermal Comfort, Urban Canopy Model, Urban Vegetation

BACKGROUND

As a typical high-density city, Singapore is going through rapid urbanization and facing serious challenges to the high Urban Heat Island effect (UHI) intensity. Urban vegetation has been widely adopted in urban design to improve the thermal environment and alleviate pedestrian heat stress.

RESEARCH GAP

The balance between the benefits and adverse effects of urban vegetation requires more profound scrutiny, with a particular emphasis on the thermal comfort considerations.

METHODS

A mechanistic urban canopy model Urban Tethys-Chloris (UT&C) (Fig. 1b) was adopted as the primary modelling tool; A unique scaled outdoor experiment SOMUCH (Fig. 1a) was selected to provide high-quality validation data for modeling; A semi-empirical wind model was integrated within the original UT&C model. Fig.2 shows significant improvements in the wind speed calculation.

1. UT&C Model and SOMUCH experiment

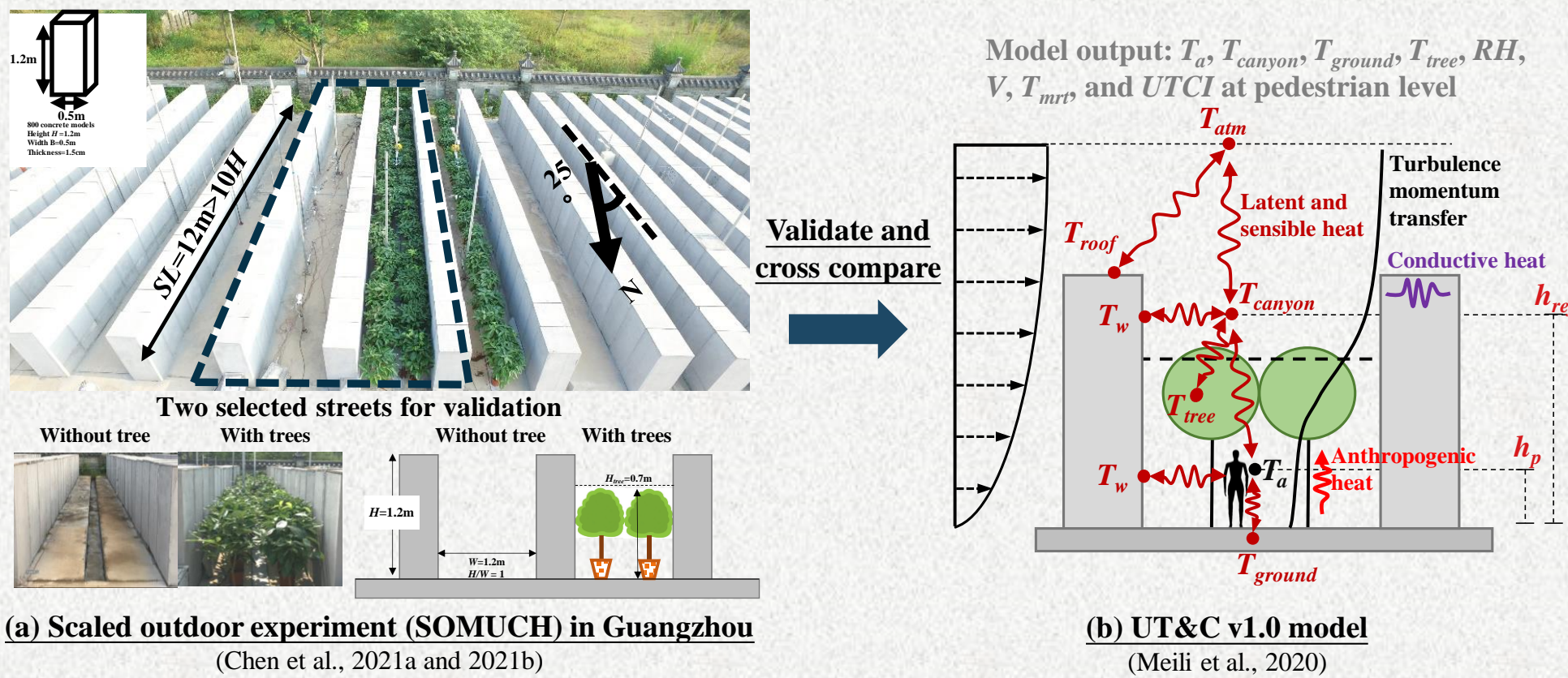


Fig. 1. (a) Scaled outdoor experiment; (b) Turbulent energy transfer in the UT&C model.

2. Validation results of modified semi-empirical wind model

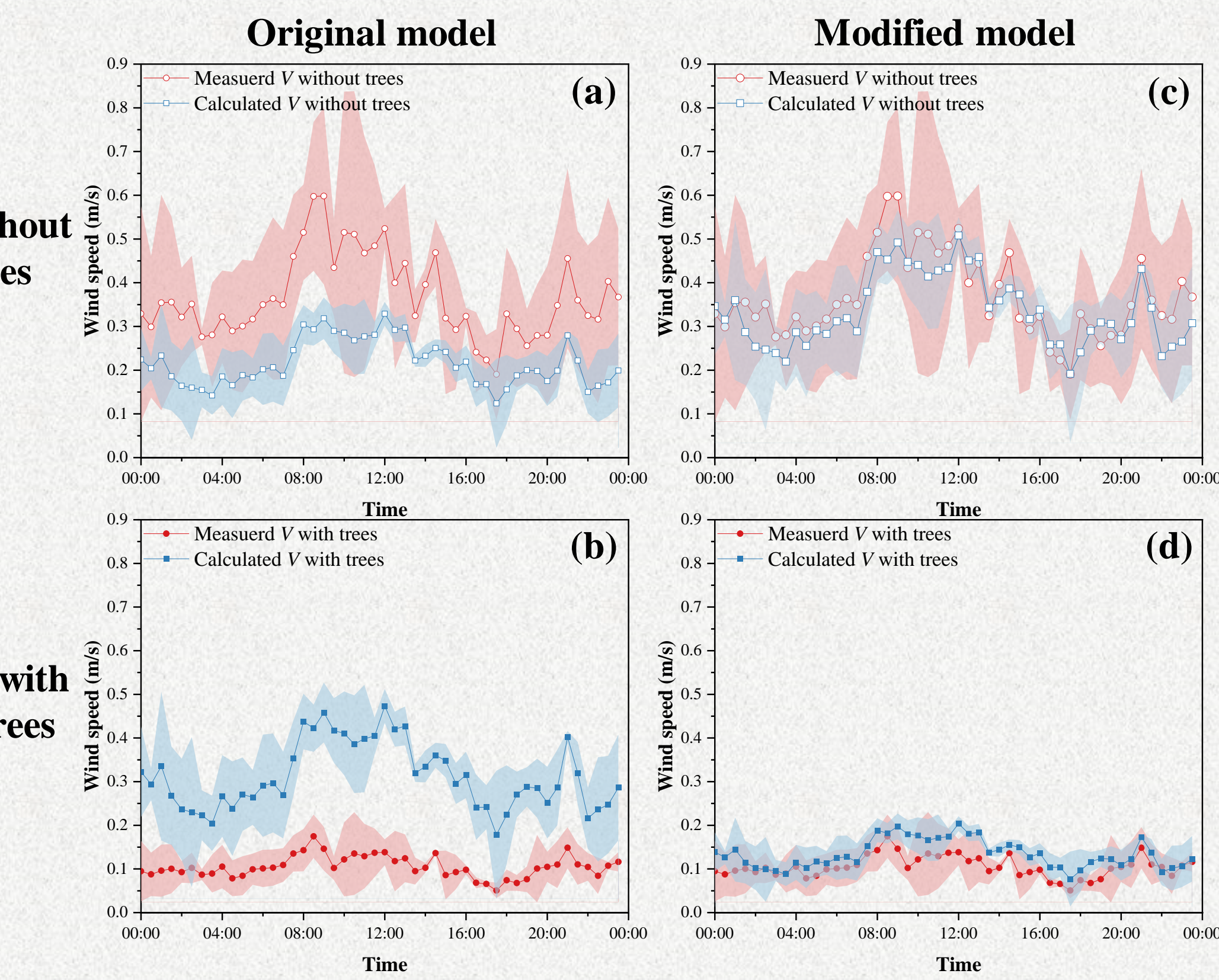


Fig. 2. Measured and calculated wind speed (V) based on the original model: (a) street without trees; (b) street with trees; and modified model: (c) street without trees; (d) street with trees.

CONCLUSION/S

Cooling effects provided by trees can be weakened in dense street canyons with larger H/W; Middle-density tree crown (LAI=4.0) is suggested after balancing the trees' performance on outdoor thermal comfort and aerodynamics; Large ($r_{tree}=5.0$ m) and middle (3.4 m) tree crown size are recommended for wide (H/W=1.0-3.0) and narrow (H/W=3.0-5.0) streets to maximize UTCI cooling effects, respectively.

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SOMUCH experiment: Jian Hang

AIM

To improve the impact of urban climate science on practicing urban planning and design, we aim to evaluate the coupling effects of tree characteristics and street morphologies on the thermal environment in high-density cities.

FINDINGS

1. Individual Effects of Tree Parameters with Fixed Street Morphology

Though greater tree density and crown size cause stronger wind reduction and higher humidity, they also can decrease air temperature and radiation, thus improving thermal comfort.

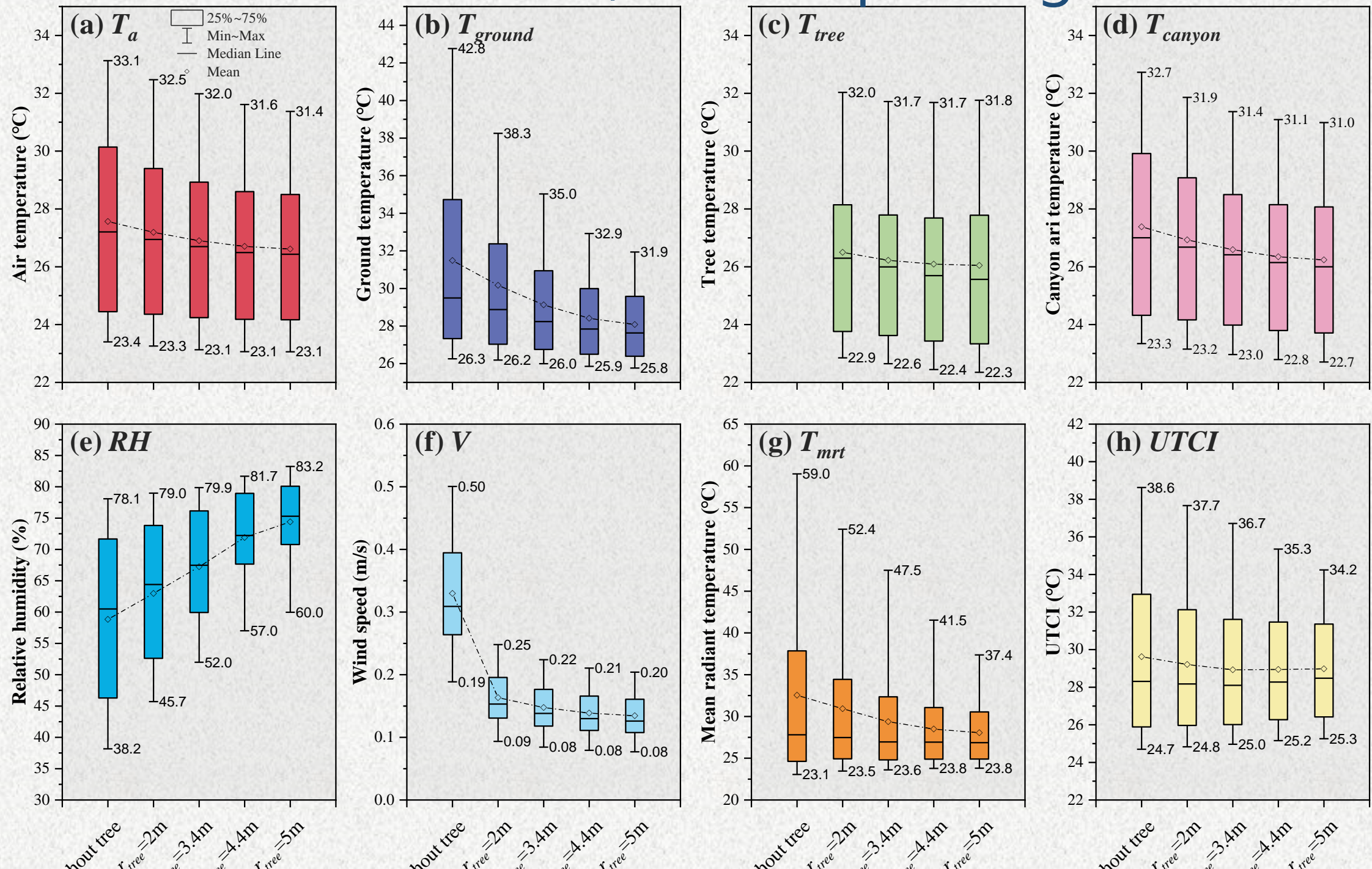


Fig. 3. Boxes of calculated parameters with various $r_{tree}=2.0-5.0$ m and fixed aspect ratio (H/W=1): (a) T_{air} ; (b) T_{ground} ; (c) T_{tree} ; (d) T_{canyon} ; (e) RH; (f) V; (g) T_{mrt} ; (h) UTCI.

2. Coupling Effects of Tree Parameters and Street Morphologies

Cooling effects of trees are weakened in dense street; LAI=4.0 and $r_{tree}=5.0$ m are recommended for wide streets, while LAI=4.0 and $r_{tree}=3.4$ m are identified as optimal values for narrow streets (H/W>3.0) to maximize UTCI cooling effects of about 4.0 °C.

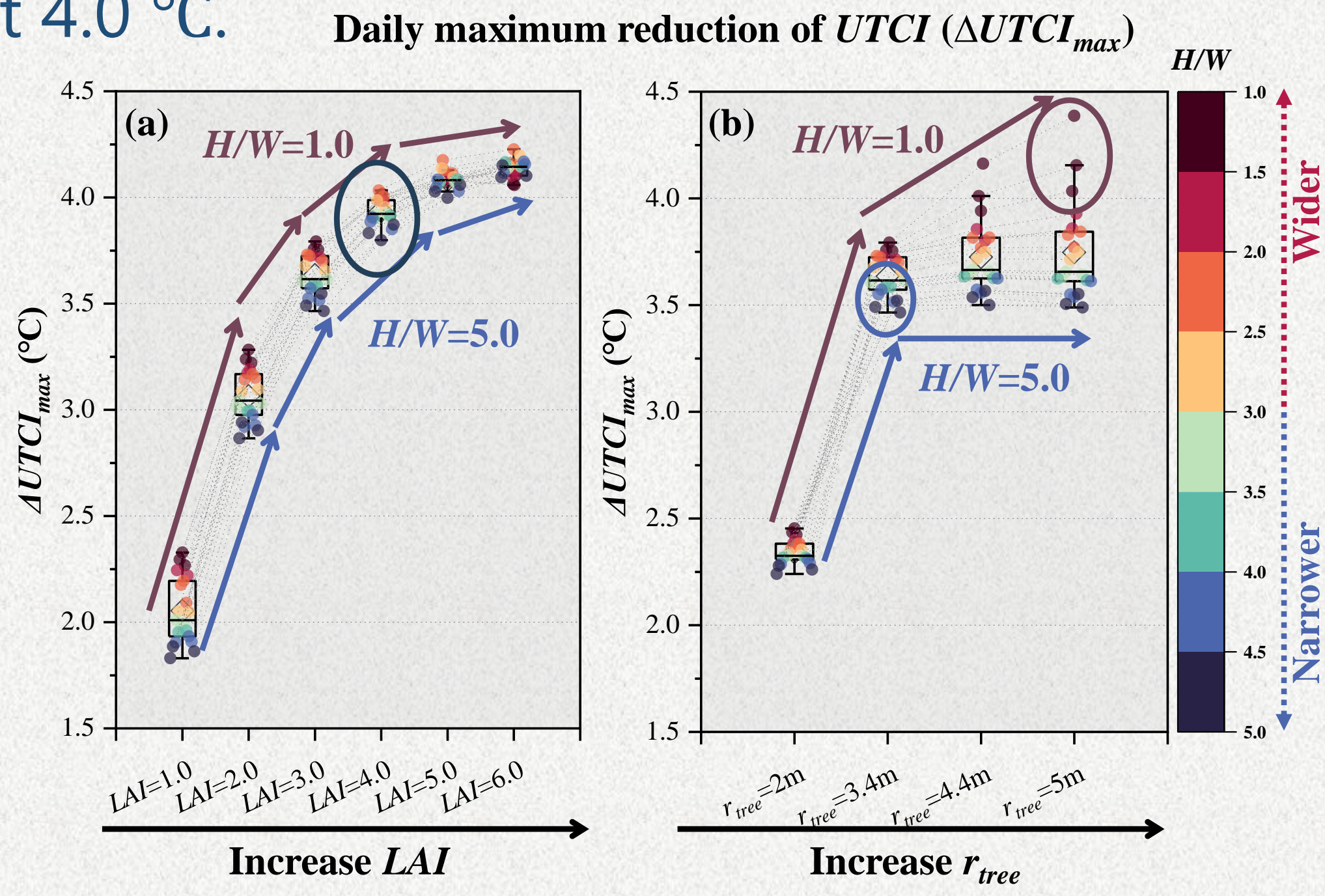


Fig. 4. Daily maximum reduction of Universal Thermal Climate Index ($\Delta UTCI_{max}$) for various H/W=1.0-5.0 and: (a) LAI=1.0-6.0; (b) $r_{tree}=2.0-5.0$ m.

<Future applications>

Urban-scale thermal comfort mapping based on the quick and feasible modeling tool; Real-time data-driven urban climate projection methods for climate resilience; Identification for areas with poor thermal comfort or high heat risk; Nature-based solutions to mitigate the Urban Heat Island effect.

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