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VTUF-3D: An urban micro-climate model to assess temperature moderation from increased vegetation and water in urban canyons

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9 September 2015 - WSCC2 Brisbane

MONASH University

Aim of research

Design overview

Validation process

Scenarios

Next steps

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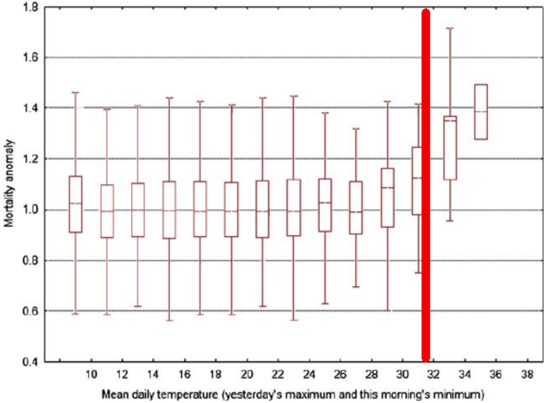
Introduction

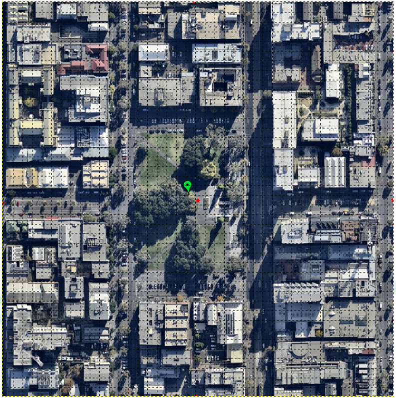
Heat health thresholds

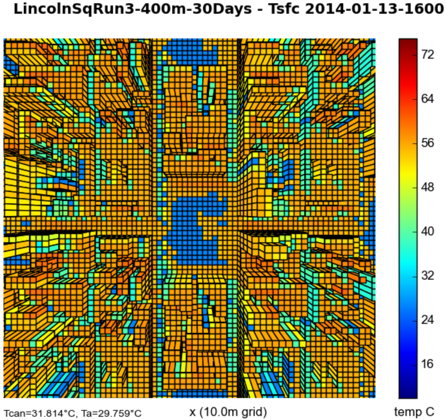


(Nicholls et al., 2008)

Trees cooling streets

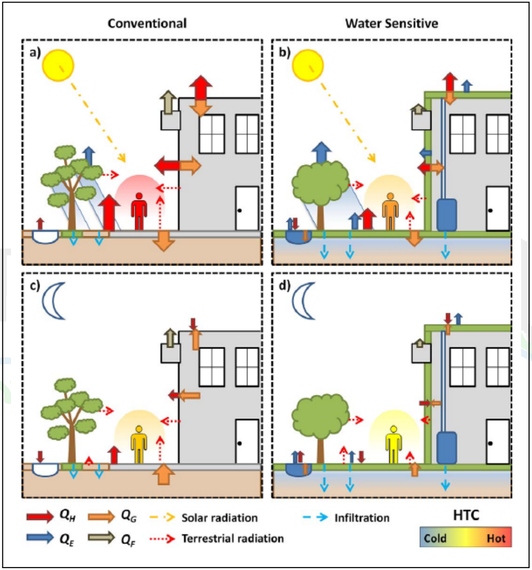
Introduction





Modelling cooling effects of trees at a microscale

CRC for Water Sensitive Cities research overview



(Coutts et al., 2013)

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Project B3.1 - Cities as Water Supply Catchments - Green Cities and Microclimate

The aim of this project is to **identify the climatic advantages** of stormwater harvesting/reuse and water sensitive urban design at building to neighbourhood scales.

To **determine the micro-climate processes and impacts** of decentralised stormwater harvesting solutions and technologies at both household and neighbourhood scales.

To **assess the impacts of these solutions on human thermal comfort and heat related stress and mortality.**

To provide stormwater harvesting strategies to improve the urban climate and benefit the carbon balance of cities.

To project the likely impact of climate change on local urban climate, with and without stormwater resuse as a mitigation strategy.

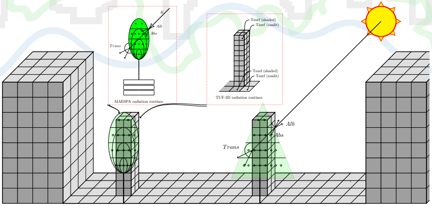
(CRC for Water Sensitive Cities, 2015)

VTUF-3D energy balance modelling with MAESPA tiles

Modifications to TUF-3D (Krayenhoff and Voogt, 2007) to resolve urban canyon radiation flux movement using placeholder vegetation structures which call MAESPA (Duursma and Medlyn, 2012) vegetation absorption, transmission, and reflection routines.

VTUF-3D uses cube shaped structures (as TUF-3D uses to represent buildings) to represent vegetation. These cubes store the surface properties and states and interact with the rest of the VTUF-3D domain.

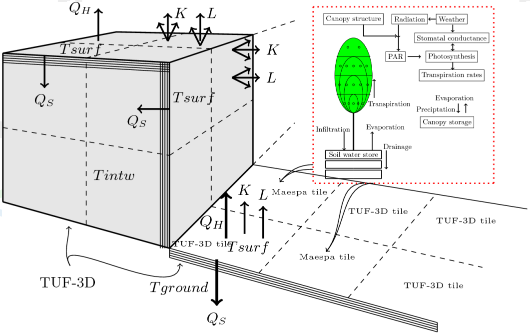
The vegetation's true shape is represented in MAESPA and calls underlying MAESPA routines to calculate the vegetation's interactions with the urban canyon and radiation movement.



Integration of MAESPA tree model into VTUF-3D radiation fluxes routines

VTUF-3D energy balance modelling with MAESPA tiles

Using a novel approach, MAESPA tiles replaces VTUF-3D ground surfaces with vegetated MAESPA surfaces and use MAESPA's photosynthesis and water cycle routines to modify VTUF-3D's energy balance calculations.
Each embedded MAESPA surface calculates a full 3 dimensional tree (along with associated soil and movement of water within the stand) and feeds results back to VTUF-3D ground surface energy balances.



VTUF-3D energy balance modelling with vegetation MAESPA tiles

MAESPA brushbox tree (*Lophostemon Confertus*) parameterization

Tree dimensions for 5x5m grid (rescale for taller/shorter):

crown radius = 2.5m, crown height = 3.75m
trunk height = 1.25m, leaf area index =2.0
crown shape = round, zht=4.0, zpd=1.6, z0ht=3.0

Leaf reflectance 3 wavelengths 0.04, 0.35, 0.05 (Fung-yan 1999)

Minimum stomatal conductance g0 = 0.01 (Determined from Melbourne Cemetery Tree)

Slope parameter g1 = 3.33 (Determined from Melbourne Cemetery Tree)

# of sides of the leaf with Stomata = 1 (Beardsell and Consodine)

Width of leaf (metres) = 0.05

CO2 compensation point = 53.06 (CO2 curves)

Max rate electron transport=105.76 (CO2 curves)

Max rate rubisco activity = 81.6 (CO2 curves)

Curvature of the light response curve =0.61 (PAR curves)

Activation energy of Jmax = 35350 (Bernacchi et al 2001)

Deactivation energy of Jmax = 200000 (Medlyn et al 2005)

XX Entropy term = 644.4338

Quantam yield of electron transport = 0.06 (PAR curves)

Dark respiration= 1.29 (PAR curves)

Specific leaf area=25.3 (25.3=Wright and Westoby 2000)

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VTUF-3D validation matrix

Scenario	Ta	Tcan	UTCI	ET	Energy balance
Preston (Coutts et al., 2007)					
Gipps/George St, Melbourne (Coutts et al., 2015)					
Lincoln Sq, Melbourne (Motazedian, 2015)					
Hughesdale					
Smith St, Melbourne (Gebert et al., 2012)					

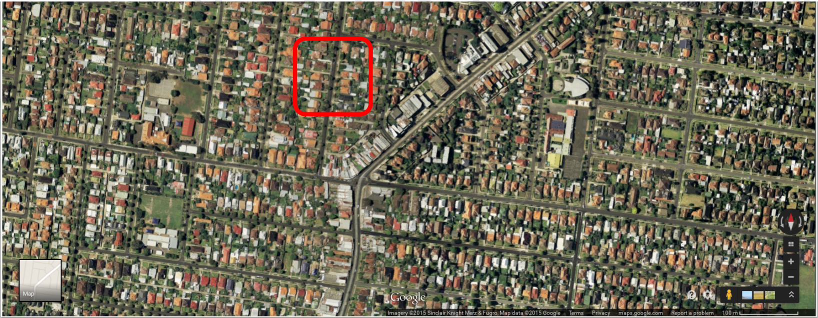
A variety of observation data allows validations of a number of different aspects of the model

Model testing and validation using Preston dataset

Preston - homogeneous, medium density.

Data set contains complete flux observations recorded 2003-2004, allowing validation of surface energy balances

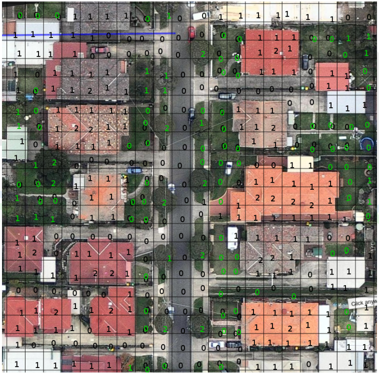
Modelled area (500x500m) chosen is representative of overall area observed by flux tower



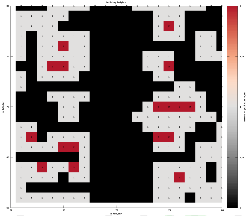
(Google 2015)

Model testing and validation using Preston dataset

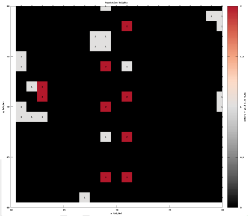
Mix of vegetation types: grass (18.5%), olive and brushbox trees (7.25%).
Medium density area (46.75% buildings). 27.5% impervious surfaces.



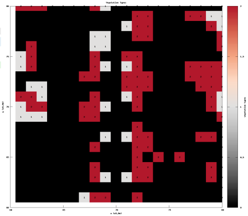
Digitization of Preston suburban street.
(1=building heights, 1=vegetation heights)



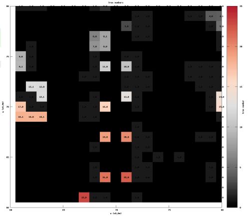
Building heights (0, 5, 10m)



Vegetation heights (0, 5, 10m)



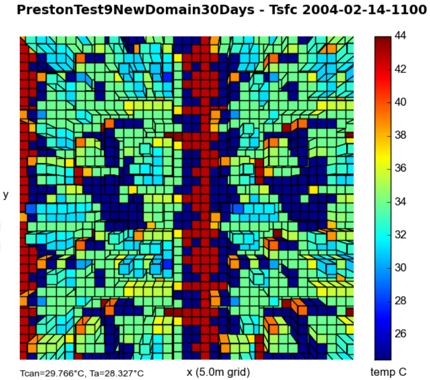
Types (grass, brushbox, olive)

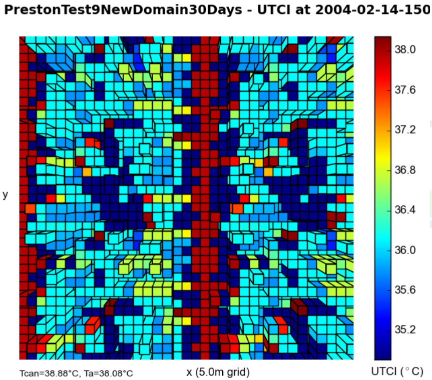


Tree numbers

Model results using Preston dataset

Hourly results for Tsfc and UTCI for 14 Februrary 2004

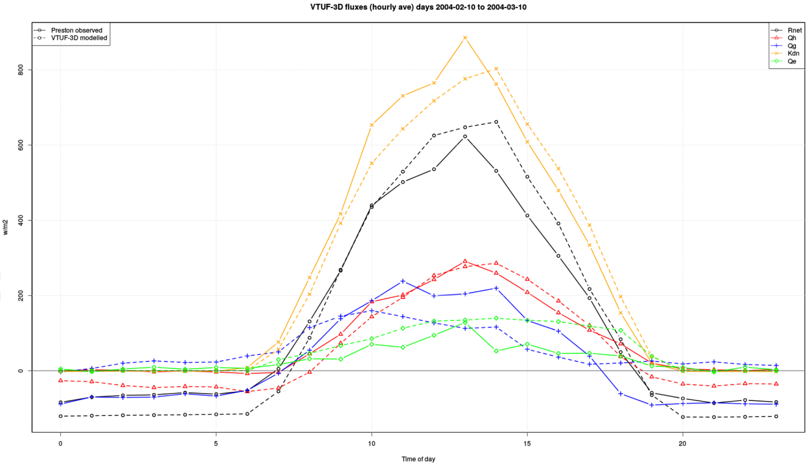




(UTCI is a human thermal comfort index combining air temperature, surface temperature, wind, humidity, radiation load, etc. into a 'feels like' equivalent temperature.)

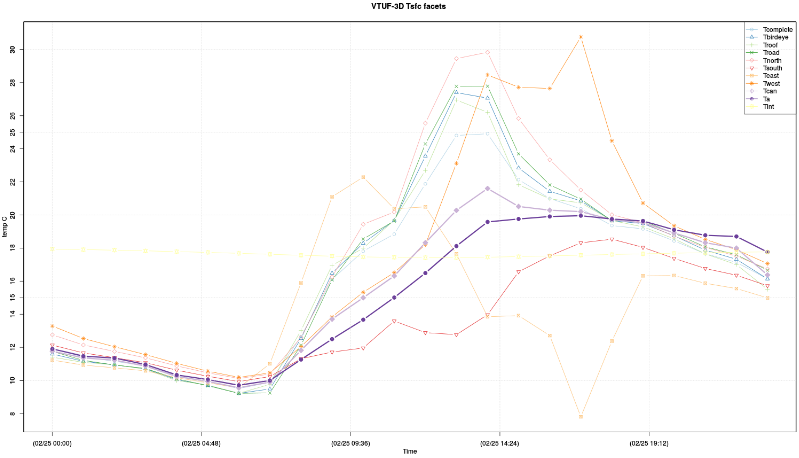
Model testing and validation using Preston dataset

30 day hourly average flux comparisons to Preston flux observations



Model results using Preston dataset

Canyon temperatures for 25 Feburary 2004, predicted canyon air temperature along with various canyon surface temperatures



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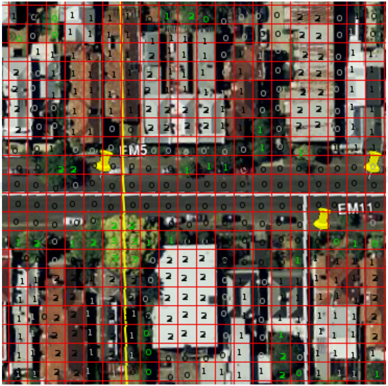
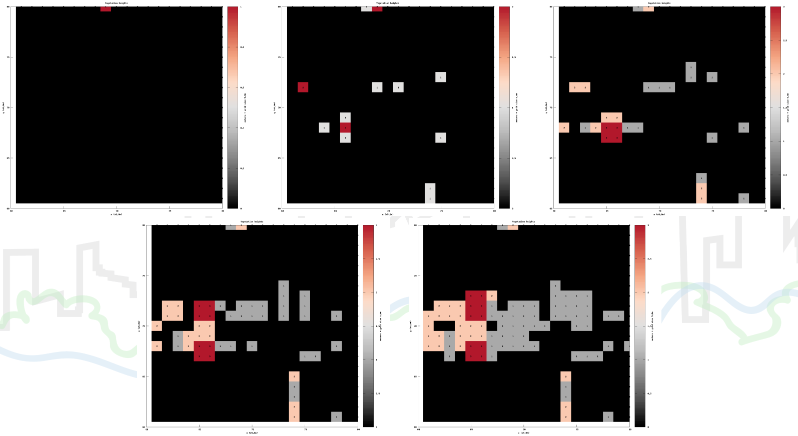
Model validations and scenarios using City of Melbourne, George and Gipps St datasets

Shallow urban canyons (ave building heights 7 and 8m, H:W 0.32 and 0.27) with varying canopy cover (45% and 12%)



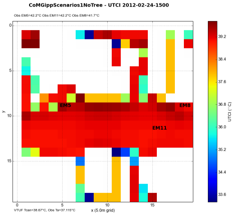
Validation against 4 and 3 observation stations located on street

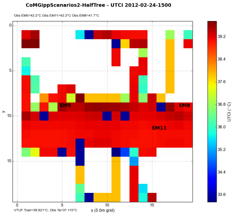
City of Melbourne Gipps St Scenarios–tree configurations

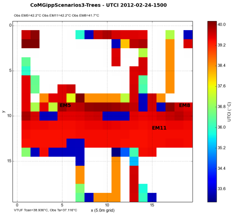


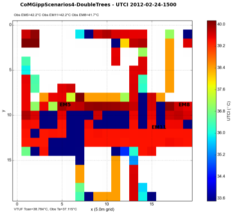
5 scenarios of 0% trees, 50% trees, existing Gipps St (100%) tree canopy cover, 200% trees, and 400% trees.

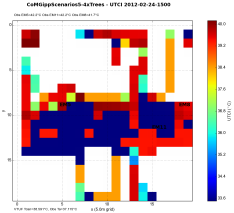
City of Melbourne Gipps St Scenarios-UTCI at 0 meters











UTCI (averaged at 0m height) maximum variations of 1.0°C between Gipps St. 0% tree scenario and 200% trees.

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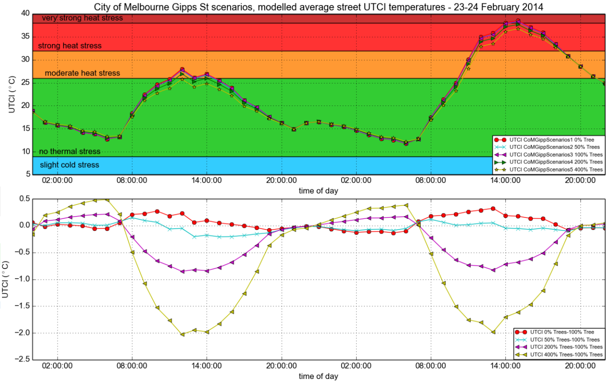
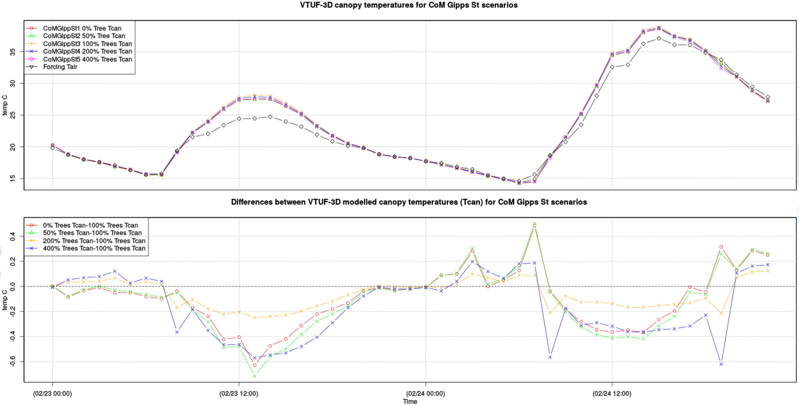
City of Melbourne Gipps St Scenarios-UTCI differences between scenarios



UTCI (averaged at 0m height) maximum variations of 1.0°C between Gipps St. 0% tree scenario and 200% trees.

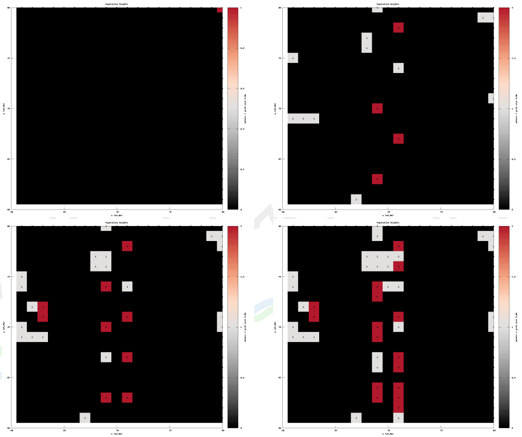
City of Melbourne Gipps St Scenarios-Canopy temperatures

Modelled Tcan of 4 scenarios over 23-24 February 2014 / Tcan differences between 100% trees and other scenarios



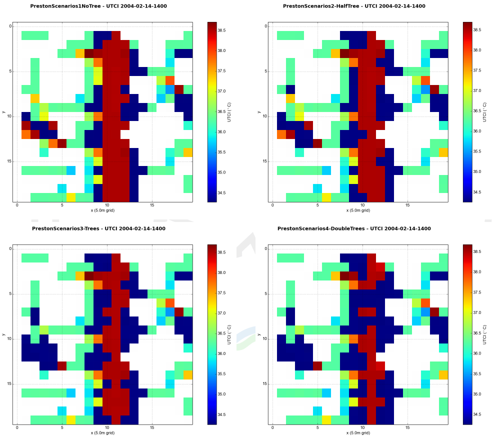
Canopy temperature differences range from 0.2°C to 0.4°C .

Preston Scenarios-tree configurations



4 scenarios of 0% trees, 50% trees, existing Preston (100%) tree canopy cover, and 200% trees

Preston Scenarios-UTCI at 0m

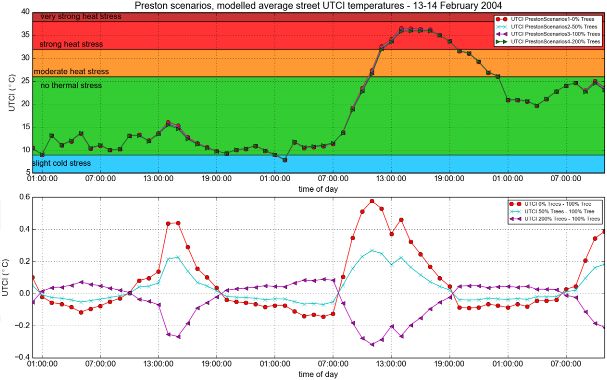


UTCI (street level, 0m, average) variations of 0.9°C between no tree scenario and 200% trees

200% trees scenario gives 0.3°C UTCI reduction over existing (100%) Preston tree canopy

Preston Scenarios-UTCI differences between scenarios

Modelled UTCI of 4 scenarios over 13-14 February 2004 / UTCI differences between 100% trees and other scenarios



UTCI (street level, 0m, average) variations of 0.9°C between no tree scenario and 200% trees

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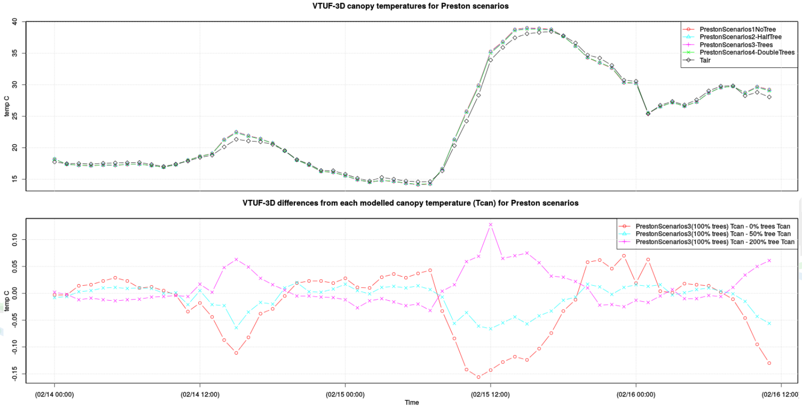
Preston Scenarios-Canopy temperatures



Modelled Tcan of 4 scenarios over 13-14 February 2004 / Tcan differences between 100% trees and other scenarios

Conclusions / Future work

Preliminary modelling with VTUF-3D shows UTCI temperature reductions of up to 1.0 C between varying tree cover scenarios and canopy temperature differences of 0.2C to 0.4C .

Completion of vegetation parameterizations (grass as well as a variety of common street trees, in addition to the olive and brushbox parameterizations)

Completion of validation scenarios

- Hughesdale
- Smith St

Sensitivity study building on and adding variations of validation scenarios to examine impact to human thermal comfort of placement and quantity of trees in urban areas

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