Microclimate Models and Application in the Urban Environment

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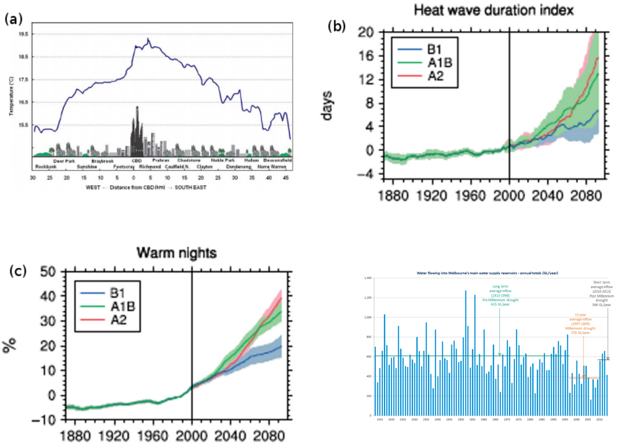
Outline



Urban heat island effects; predicted increasing extremes for Australia; Melbourne's water supply

(Coutts et al., 2010; Alexander and Arblaster, 2009; Melbourne Water, 2014)

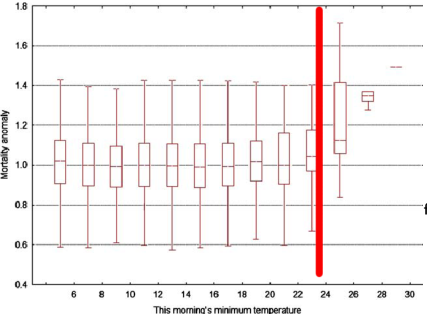
Increasingly vulnerable Australian demographics

- **Population growth** - In 2007, 21.0 million people
  30.9 to 42.5 by 2056
  33.7 and 62.2 by 2101.
- **Ageing population** - Median age, 36.8 years in 2007
  38.7 to 40.7 years in 2026
  41.9 to 45.2 years in 2056.
  In 2007, 13% of population 65 years and over
  23% to 25% in 2056
- **Increased urbanisation** - In 2007, 64% lived in a capital city.
  By 2056, increase to 67%.

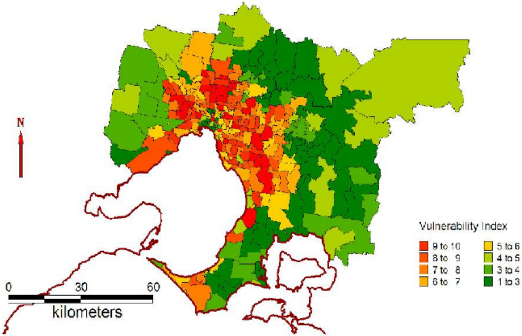
(http://www.abs.gov.au/Ausstats/abs@.nsf/mf/3222.0)

Melbourne heat index thresholds and spatial vulnerability of high risk populations during hot weather

Melbourne: Daily min. temp. 24 °C threshold

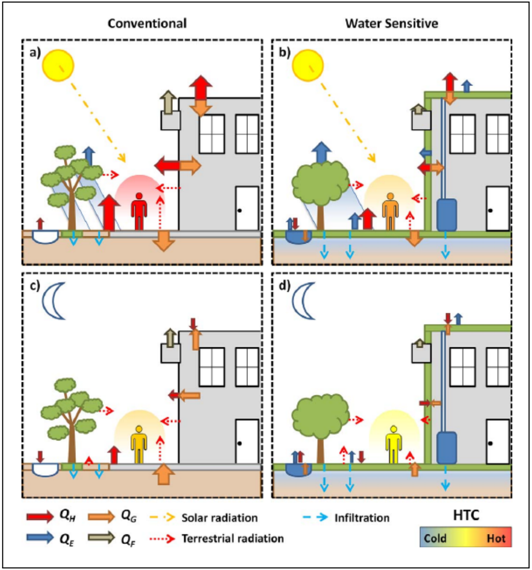


(Nicholls et al., 2008; Loughnan et al., 2010)



Melbourne vulnerability index based on UHI, land use, urban form, demographics (age, medical conditions, socio-economic, social isolation)

CRC for Water Sensitive Cities research overview



(Coutts et al., 2013)

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

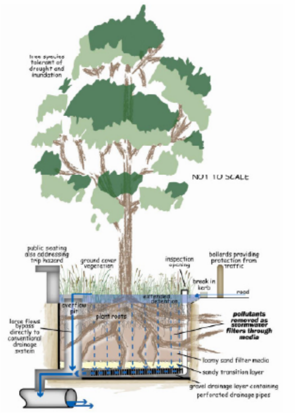
The aim of this project is to identify the climatic advantages of stormwater harvesting/reuse and water sensitive urban design at building to neighbourhood scales.

- 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)

Water Sensitive Urban Design (WSUD) as mitigation/adaptation

Are there positive climatic impacts on human thermal comfort?

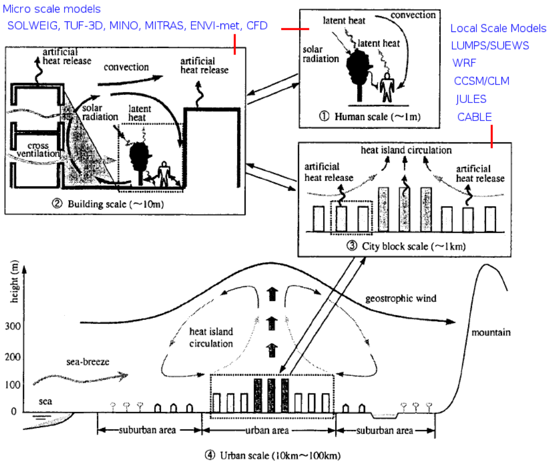


Design of a tree-pit (FAWB, 2009)

Tree pits and other WSUD features in urban areas.
(FAWB, 2008)

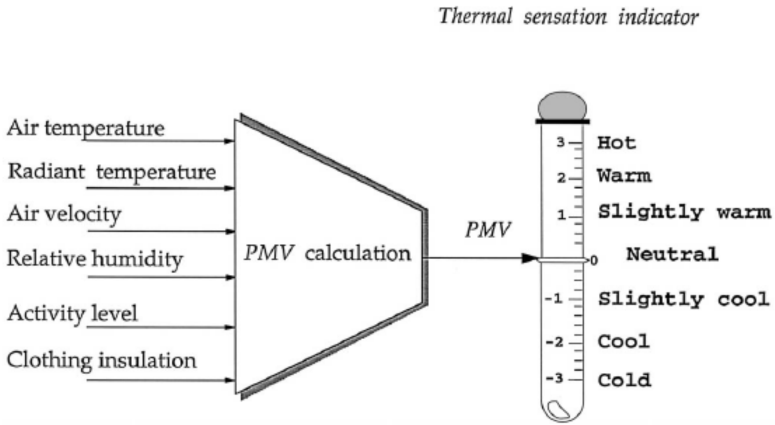
Modelling WSUD

Observations can only examine what already exists. Modelling is needed to examine a wider range of scenarios, technologies, and climatic benefits at a variety of scales.



(Adapted from Murakami et al. 1999)

Required inputs to model HTC

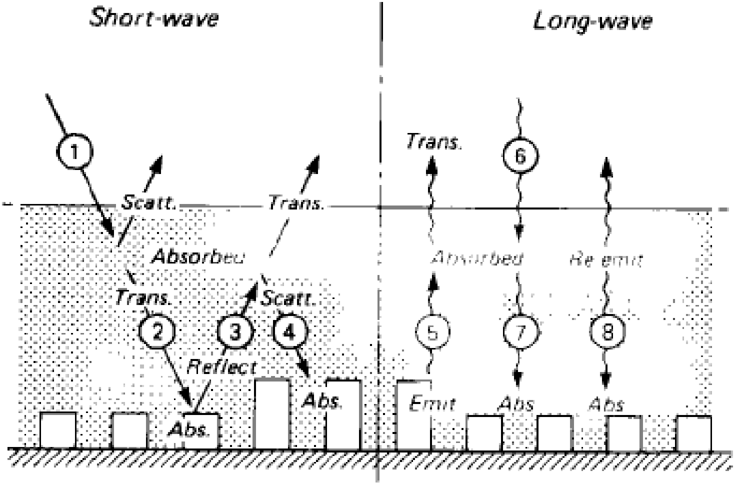


PMV and thermal sensation (Hamdi et al., 1999)

Modelling

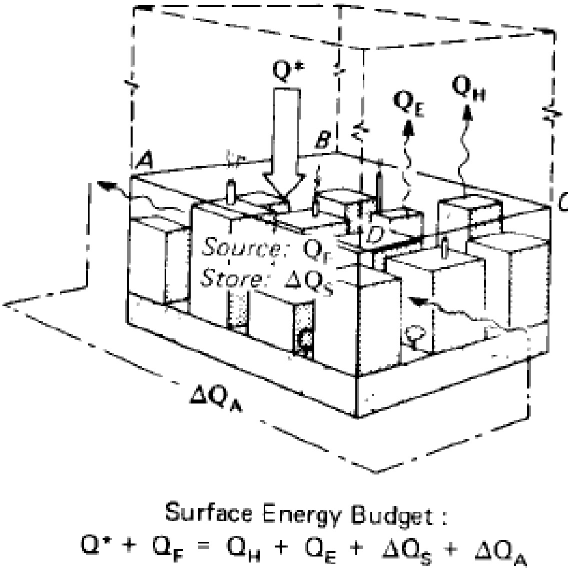
- Modelling is just a simplified view of a complex system
- Besides climate models, other models include road maps, financial spreadsheets
- In reducing complexity, detail will be lost.
- Usefulness of results depend on trade-off of computational intensity, detail of results, technique used.

Outline



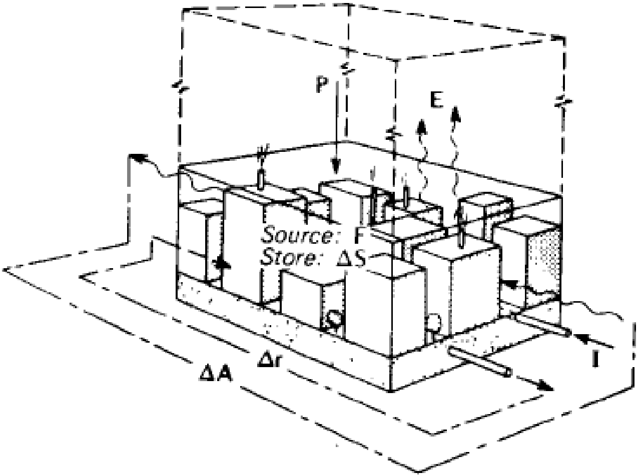
Surface Radiation Budget : Q* = K↓ – K↑ + L↓ – L↑

($Q*$ net radiation, K shortwave up/down, L longwave up/down)
(Oke, 1988)



($Q*$ net radiation, Qf anthropogenic heat, Qh sensible heat, Qe latent energy, Qs storage heat, Qa advected heat) (Oke, 1988)

Urban surface water budget

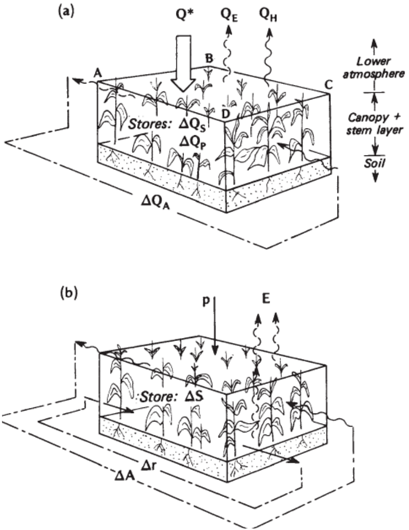


Surface Water Budget :

$$p + F + I = E + \Delta r + \Delta S + \Delta A$$

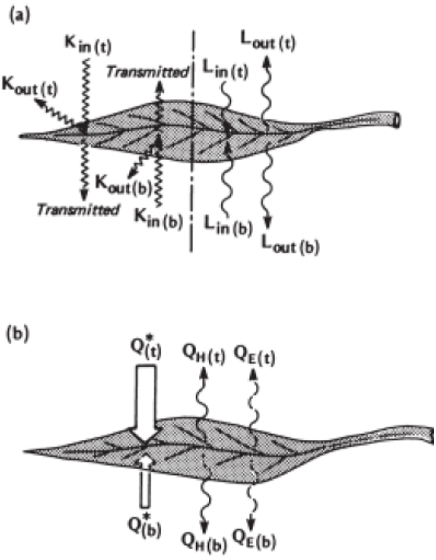
(p precipitation, F released from combustion, I urban water supply, E evaporation, r runoff, S storage, A advection) (Oke, 1988)

Soil-plant-atmosphere-continuum



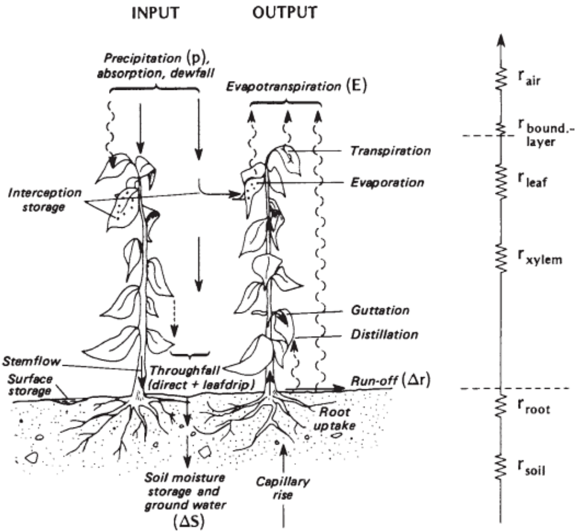
Schematic depiction of fluxes involved in (a) the energy and (b) the water balances of a soil-plant-air volume (Oke 1988)
(Qp biochemical energy storage)

Soil-plant-atmosphere-continuum



Schematic depiction of fluxes involved in (a) the radiation budget and (b) the energy balance of an isolated leaf (Oke, 1988)

Soil-plant-atmosphere-continuum



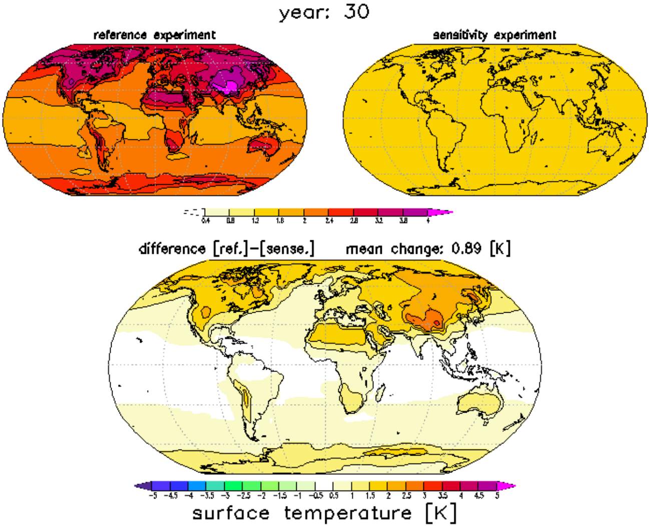
The water balance and internal flows of water in a soil-plant-atmosphere system. At the right is the electrical analogue of the flow of water from the soil moisture to the atmospheric sink via the plant system. (Oke, 1987)

Outline

General Circulation Models (GCM)

- Atmospheric general circulation models (GCM) - modelling radiation, heat, water vapour and momentum fluxes across the land-surface atmosphere interface.
- GCM models similar to numerical weather prediction (NWP) models both in design and modelling code,
- GCM models are longer running (months to years) and incorporate a large number of interactions (atmosphere, oceans, ice, and land), some of which might have been parametrized in NWP runs.

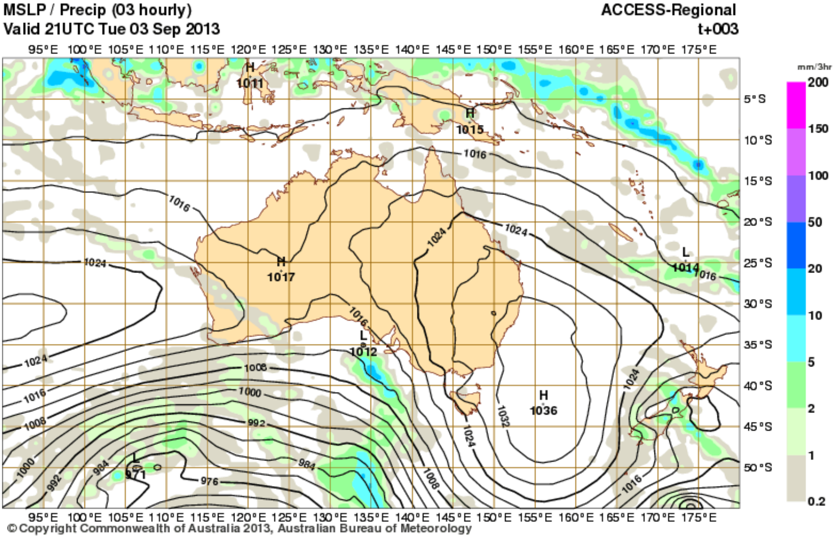
Global scale



Monash Simple Climate Model (Dommenget and Flöter, 2011)

Numerical weather prediction (NWP)

- NWP - Numerical weather prediction (NWP) models solve a series of differential equations using current weather conditions to predict future weather conditions.
- Designed for short term projection runs of days to weeks using very accurate input data of current weather conditions.
- Resolution of NWP at global or regional scale not sufficient to resolve urban areas.
- With tile or mosaic surface exchange schemes parametrizations, model a percentage of a gridbox containing the urban surfaces.
- Results can only be seen at next level up, not at the urban level. Resolving greater complexity within urban areas (i.e. flows around buildings) is generally not possible with NWP schemes.

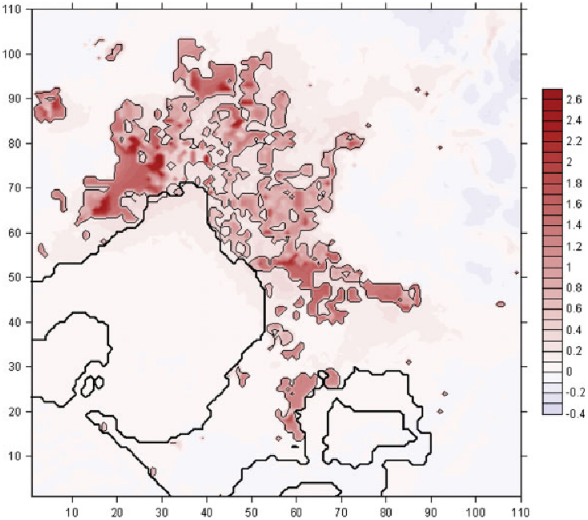


Forecast for 07:00 AEST on Wednesday 4 September 2013 (BOM 2013)

Parametrizations, Land surface schemes (LSS)

- Model parametrization - Processes that cannot be directly modelled - smaller than the grid resolution of the model, or for model efficiency, estimates of values are made, based on observations (or other means of estimating reasonable values) instead of being calculated.
- Land surface schemes (LSS) are designed to calculate the temporal evolution of energy and fluxes between land and atmosphere. Implementations can vary greatly in complexity. The simplest will treat the land as flat bare soil. Complexity can be added accounting for soil and vegetation interactions. The most complex will incorporate processes of photosynthesis and respiration.

Local scale



Change in mean nighttime (02 : 00) screen level temperature change from the current urban development, to that proposed by the Melbourne 2030 planning strategy. Areas within the contours are statistically significant at the 95% confidence level. (Coutts et al., 2008)

Micro-scale modelling

(brickplayer.com)

Computatial fluid dynamics (CFD) methods

Navier-Stokes Equations
3 – dimensional – unsteady

Glenn Research Center

Coordinates: (x,y,z)
Velocity Components: (u,v,w)

Time : t
Density: ρ
Total Energy: Et

Pressure: p
Stress: τ

Heat Flux: q
Reynolds Number: Re
Prandtl Number: Pr

Continuity:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

X – Momentum:

$$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right]$$

Y – Momentum:

$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z}\right]$$

Z – Momentum

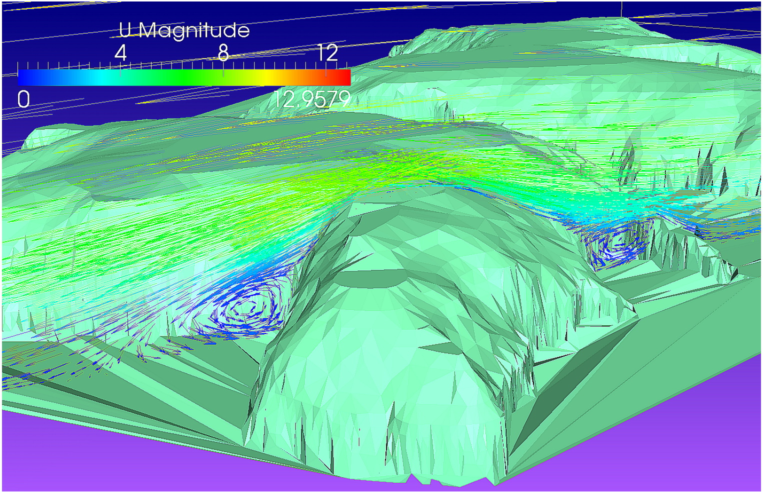
$$\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right]$$

Energy:

$$\frac{\partial(E_T)}{\partial t} + \frac{\partial(uE_T)}{\partial x} + \frac{\partial(vE_T)}{\partial y} + \frac{\partial(wE_T)}{\partial z} = -\frac{\partial(up)}{\partial x} - \frac{\partial(vp)}{\partial y} - \frac{\partial(wp)}{\partial z} - \frac{1}{Re_r Pr_r}\left[\frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} + \frac{\partial q_z}{\partial z}\right]$$

$$+ \frac{1}{Re_r}\left[\frac{\partial}{\partial x}(u\,\tau_{xx} + v\,\tau_{xy} + w\,\tau_{xz}) + \frac{\partial}{\partial y}(u\,\tau_{xy} + v\,\tau_{yy} + w\,\tau_{yz}) + \frac{\partial}{\partial z}(u\,\tau_{xz} + v\,\tau_{yz} + w\,\tau_{zz})\right]$$

Navier-Stokes Equations, relating the velocity, pressure, temperature, and density of a moving fluid. (Nasa 2013)



CFD study of Air Flow over Complex Terrain
(Fabre et al. 2012)

CFD methods

- At micro-scales, computational fluid dynamics (CFD) can be used to model flows around an urban landscape, including features such as buildings and trees.
- Ground-up approach (as opposed to GCM), starting with the smallest interactions at a detailed level and building those up to a larger picture.
- Based on the Navier-Stokes equations, which describe the motion of fluids in 3 dimensions.

CFD methods

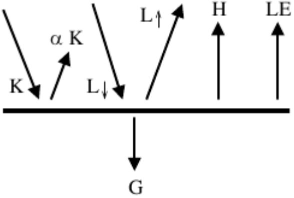
Solved in 3 different ways:

- Direct Numerical Simulation (DNS) - DNS attempts to solve all the spatial scales within the flows, very computationally intense, suitable for only the smallest simulations.
- Large Eddy Simulation (LES) reduces the computational intensity through low-pass filtering, that is, filtering out the smaller scale pieces of the solution and concentrating on the larger scaled pieces.
- Reynolds Averaged Navier-Stokes (RANS) uses mathematical techniques to simplify solutions by separating fluctuating and averaging pieces.

Energy balance models partition known quantities of shortwave and longwave radiation into energy balance budget components.

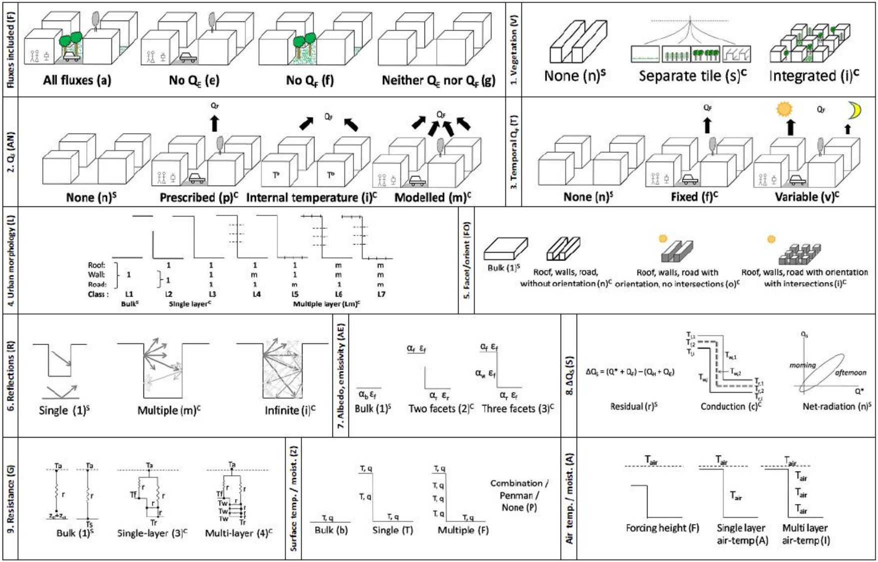
$$(1-\alpha)(Ksf + Kdf) + \varepsilon L\downarrow - L\uparrow - G - H - LE = 0$$

A less intensive approach (compared to CFD), often used by local and micro-scaled models.



Schematic of the energy balance for a surface. The direction of the arrows indicate the direction of positive flux densities.
(Harman, 2003)

Characteristics used to classify energy balance models

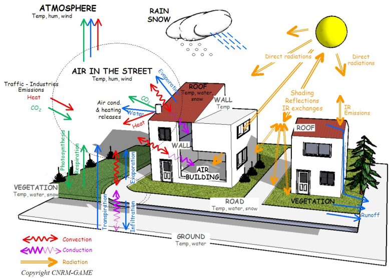


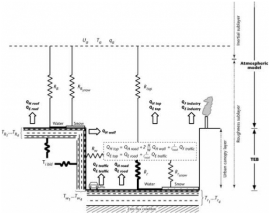
(Grimmond et al., 2010)

Outline

Local scaled models

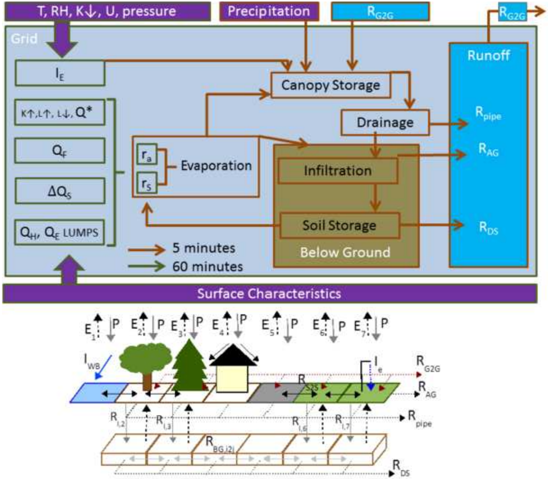
- Town Energy Balance (TEB), (Masson, 2000)
  Single canyon, energy balances of three surfaces





(CNRM-GAME 2010)

Local scaled models



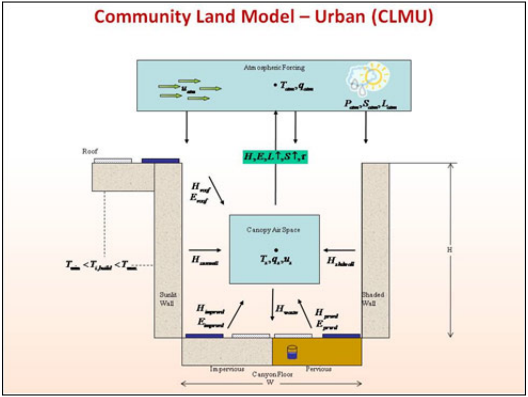
Local-scale Urban Meteorological Parameterization Scheme (LUMPS)/Surface Urban Energy and Water Balance Scheme (SUEWS), (Järvi et al., 2011)

Local scaled models

- WRF (Chen et al., 2004; Kusaka et al., 2001) - meso scaled model coupled with Noah land surface model (LSM)
- Urban canyons are parameterized into a simplified 2-D symmetrical infinite lengthed geometry, much like TEB.
- Water - simple 'very thin bucket scheme', that is surfaces are treated as impervious and well drained.
- A single layer vegetation model is used to calculate latent energy fluxes.
- Urban areas grid cells - setting percentages of surfaces and features.

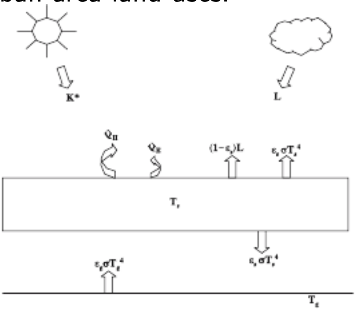
Local scaled models

- Community Climate System Model (CCSM) (Vertenstein et al., 2004)
- Global scaled but can run in single point mode.
- Urban canyon modelling similar to TEB.



CLM urban canyon modelling (UCAR, 2011)

- JULES (Joint UK Land Environment Simulator) is based on MOSES (Met Office Surface Exchange System)
- Highly simplified urban canopy module using a canopy of concrete to model radiation exchanges with the underlying soil.
- It uses the Penman-Monteith equation to calculate latent energy fluxes.
- Tiled scheme of heterogeneous surfaces in order to resolve urban area land uses.



Surface energy balance of MOSES urban canopy model (Best et al., 2006)

Local scaled models

- CSIRO Community Atmosphere Biosphere Land Exchange (CABLE) (Kowalczyk et al., 2006)
- Scaled down GCM model coupled with land surface scheme (LSS) module.
- Recent addition of TEB based urban module.

Outline

Micro scaled models - CFD based

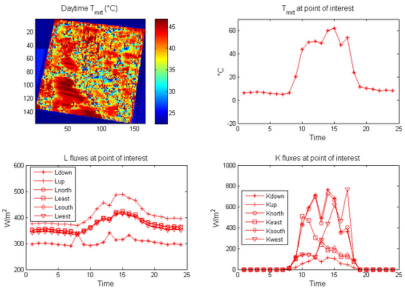
- MIMO (Kunz et al., 2000) - Originally designed to model microscale wind flow to look at pollution dispersion in urban areas. Based on solving Reynolds-averaged Navier-Stokes (RANS) equations.
- MITRAS (Mikroskaliges Chemie, Transport und Strömungsmodell) (Schlunzen et al., 2003). Also based on Reynolds-averaged Navier-Stokes (RANS) equations.
- CFD frameworks such as OpenFOAM (OpenFOAM 2011) or STAR-CD (CD-adapco 2011). C++ libraries to solve a wide variety of CFD related problems such as incompressible / compressible flows, particle tracking flows, and heat transfers as well as methods to create customized solvers. Meshes of various types are provided to be configured into any shape with any number of faces.

Micro scaled models - CFD based

- ENVI-met (Bruse, 1999) - three-dimensional non-hydrostatic model based on CFD solving of Navier-Stokes equations using finite difference numeric methods.
- Freeware, friendly GUI to generate modelling domains and graph results.
- ENVI-met provides variables describing energy fluxes (longwave, shortwave, sensible and latent), weather conditions (temperature, wind, humidity) at different levels of the domain (2D surface points as well as 3D atmospheric points)
- Variety of features (buildings of different materials, different types of vegetation, pervious and impervious surfaces of different types, and configurable layers of soil moistures).
- Mean Radiant Temperature and Predicted Mean Vote (PMV) support HTC modelling.
- Computationally intensive, runs in nearly real time (24 hours of simulation will require 24 hours of computation).

Micro scaled models

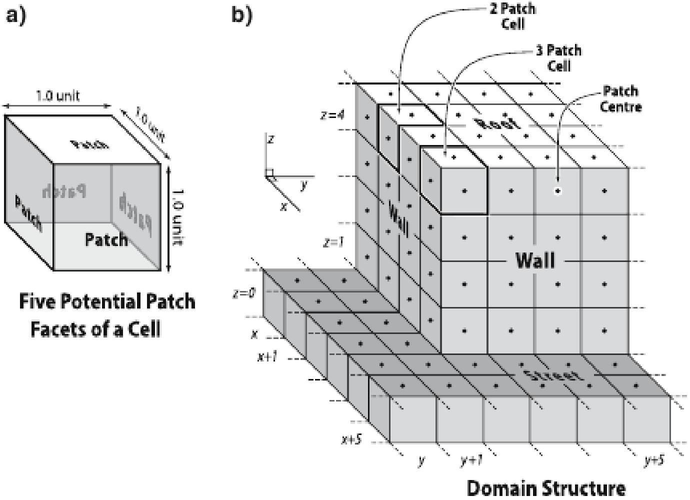
- SOLWEIG (Lindberg et al., 2008) - simulates spatial variations of mean radiant temperature and 3D fluxes of longwave and shortwave radiation.
- Vegetation only casts shadows, water is not supported.
- Can capture much of the influence of increased vegetation (i.e. shading) but not all (evaportranspiration) as it only models longwave and shortwave radiation fluxes.



Micro scaled models

- TUF-3D (Krayenhoff and Voogt, 2007) - 3D raster model, simulates energy balances, modelling radiation, conduction, and convection in order to predict fluxes of sensible heat, conduction, and radiation fluxes.
- VTUF-3D model including vegetation and latent energy will be described in more detail soon.

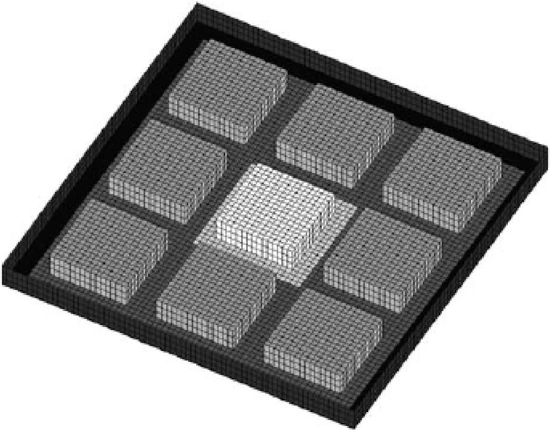
Temperatures of Urban Facets in 3D (TUF-3D) model structure



(Krayenhoff and Voogt, 2007, p. 437)

Basic cubic cell and surface patch structure of TUF-3D

TUF-3D domains

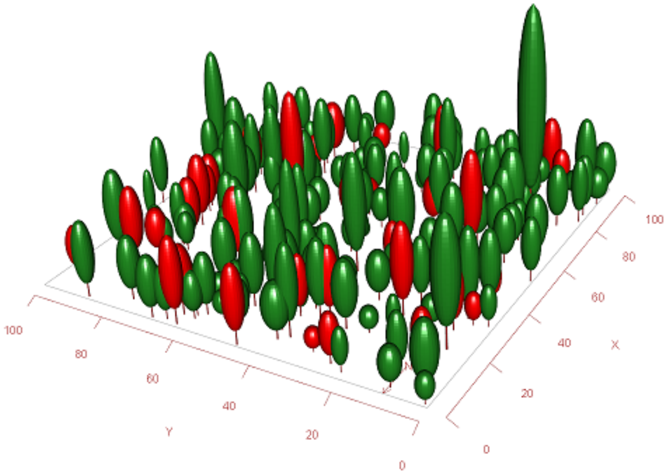


(Krayenhoff and Voogt, 2007, p. 437)

An example TUF-3D domain with a bounding wall and the sub-domain S_d (chosen to coincide with the central urban unit) in lighter shades

MAESPA tree model

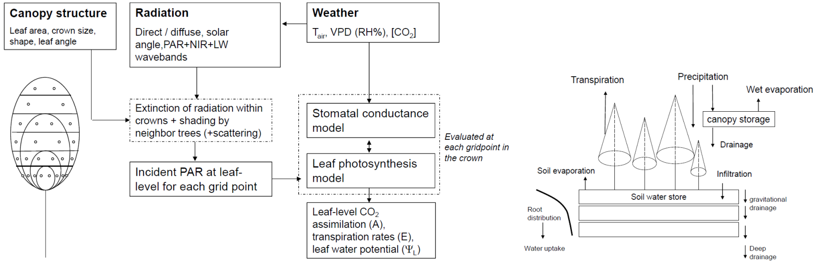
MAESPA can model a single tree along with its associated soil, canopy, soil water storage, and transpiration or be scaled up to model a forest stand.



(Duursma and Medlyn, 2012)

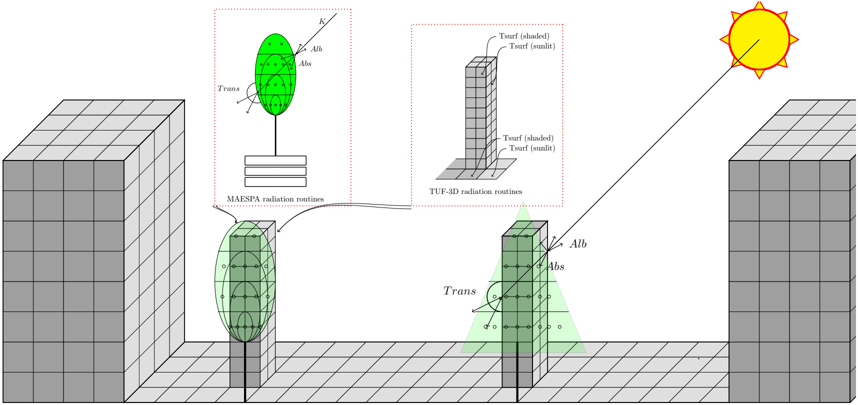
MAESPA tree model

MAESPA is a soil-plant-atmosphere model and provides forest canopy radiation absorption and photosynthesis functionality, in addition to water balances at fine temporal and spatial scales.



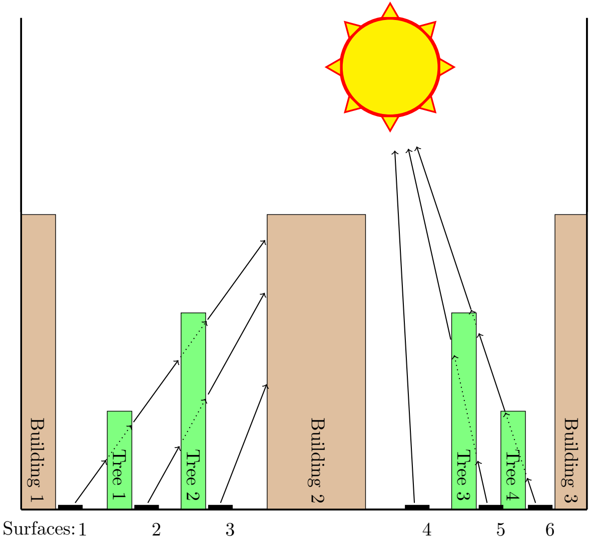
(Duursma and Medlyn, 2012)

MAESPA process and water balance flowcharts

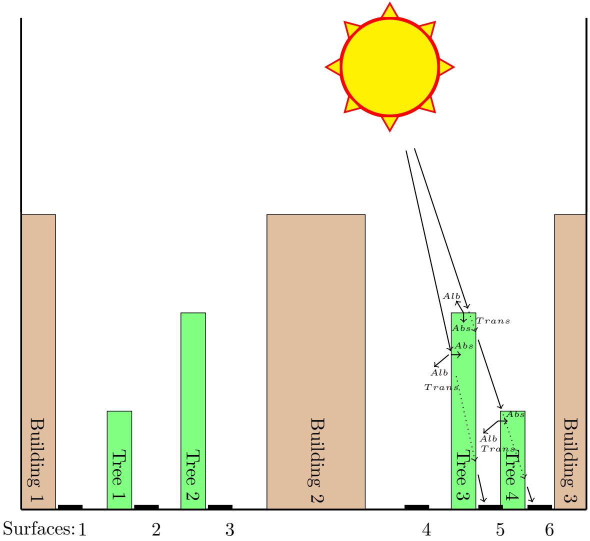


VTUF-3D/MAESPA vegetation/radiation interactions

Design - VTUF-3D modified shading

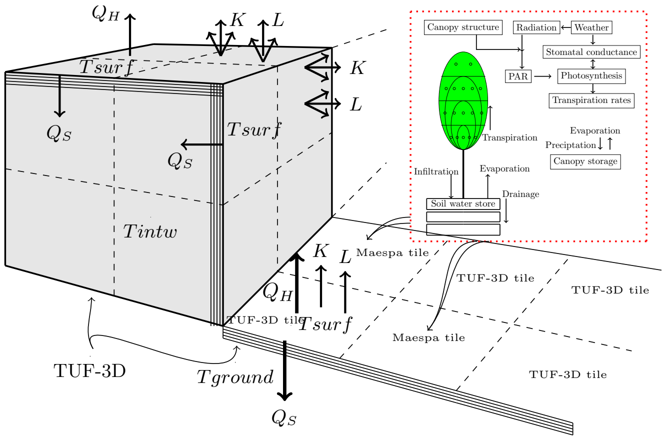


VTUF-3D modified shading, timestep ray tracing



VTUF-3D modified shading, reverse ray tracing

VTUF-3D energy balance modelling with MAESPA tiles interactions



VTUF-3D energy balance modelling with MAESPA tiles

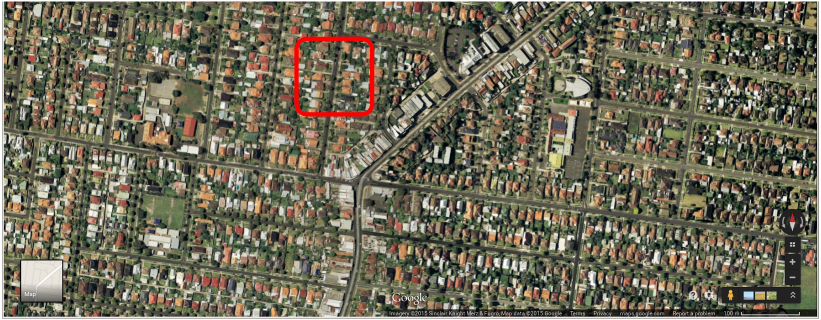
MAESPA brushbox tree (*Lophostemon Confertus*) parameterization

- 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)

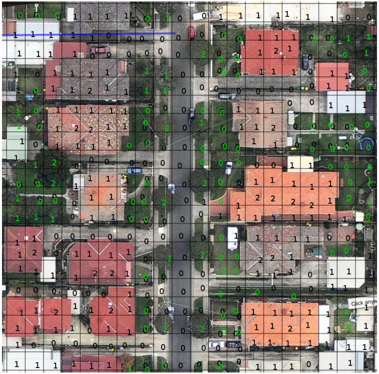
Model testing and validation using Preston dataset

- 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

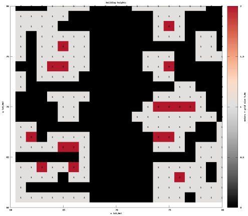


(Google 2015)

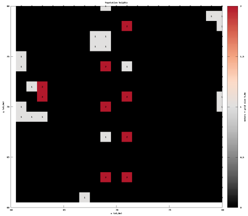
Mix of vegetation types: grass (18.5%), olive and brushbox trees (7.25%).
Medium density area (46.75% buildings). 27.5% impervious surfaces.



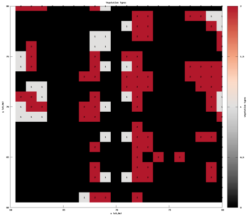
Digitization of Preston suburban street.
(1=building heights, 1=vegetation heights)



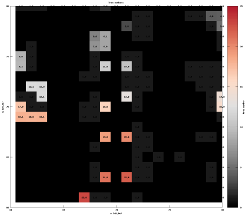
Building heights (0, 5, 10m)



Vegetation heights (0, 5, 10m)



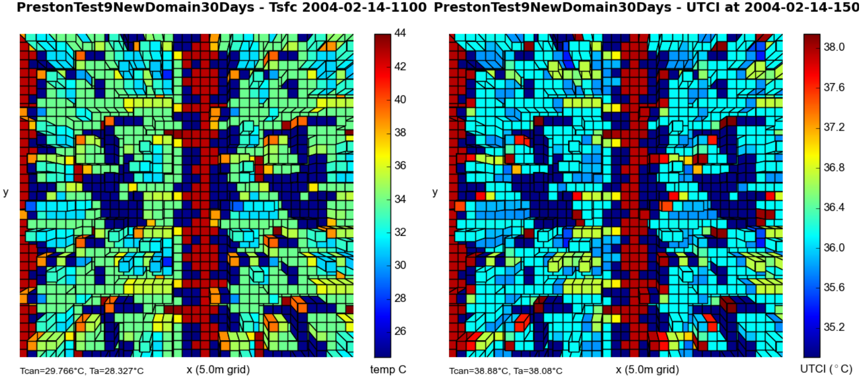
Types (grass, brushbox, olive)



Tree numbers

Model results using Preston dataset

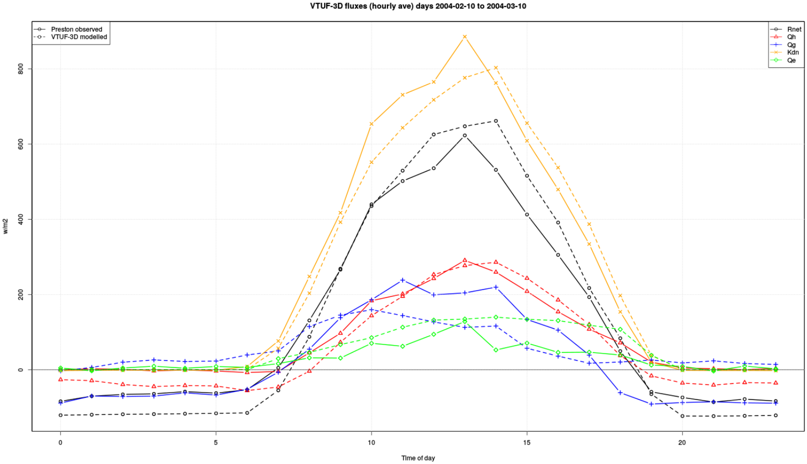
Hourly results for Tsfc and UTCI for 14 Februrary 2004



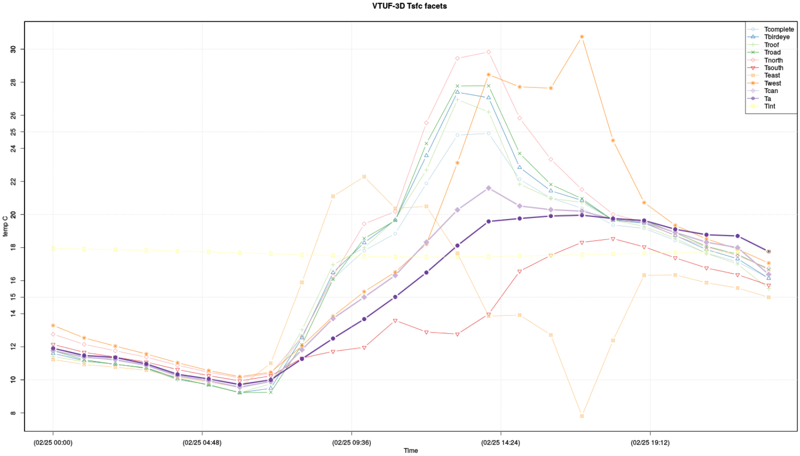
(UTCI is a human thermal comfort index combining air temperature, surface temperature, wind, humidity, radiation load, etc. into a 'feels like' equivalent temperature.)

Model testing and validation using Preston dataset

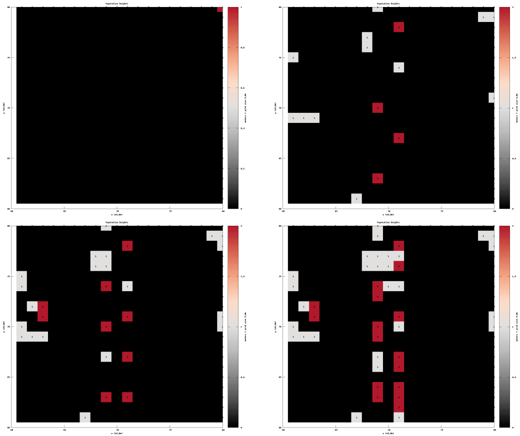
30 day hourly average flux comparisons to Preston flux observations



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

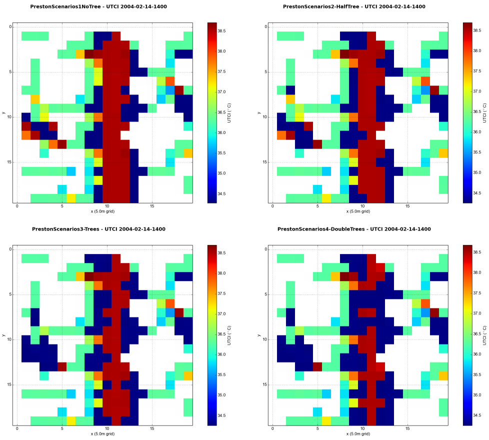


Preston Scenarios-tree configurations



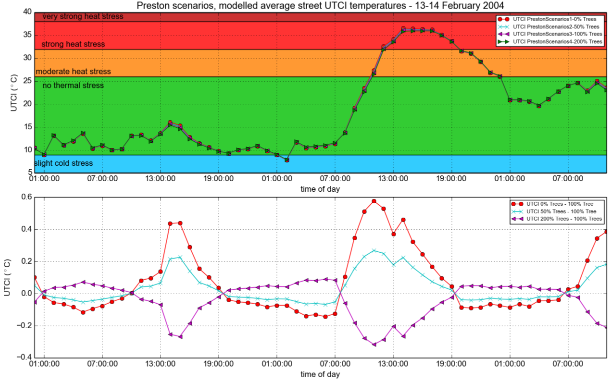
- 4 scenarios of zero trees, half trees, existing Preston tree canopy cover, and double trees

Preston Scenarios-UTCI at 0m



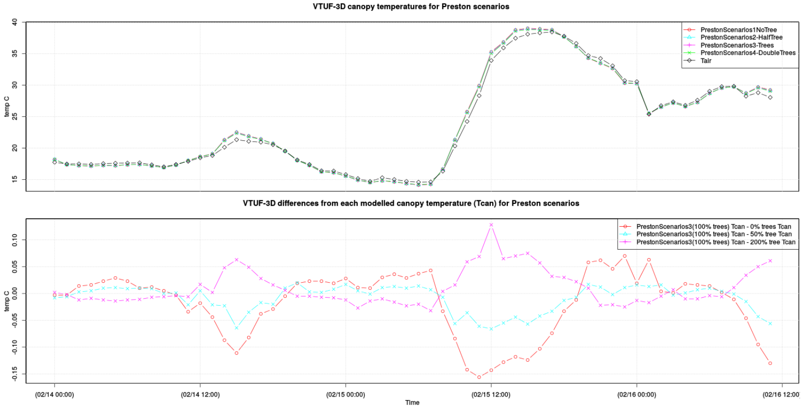
- UTCI (street level, 0m, average) variations of 0.9°C between zero tree scenario and double trees
- Double trees scenario gives 0.3°C UTCI reduction over existing Preston tree canopy

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 double trees
- Double trees scenario gives 0.3°C UTCI reduction over existing Preston tree canopy

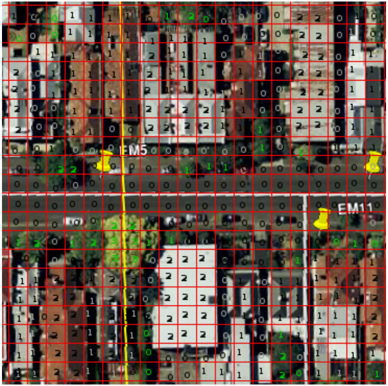
Preston Scenarios-Canopy temperatures



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

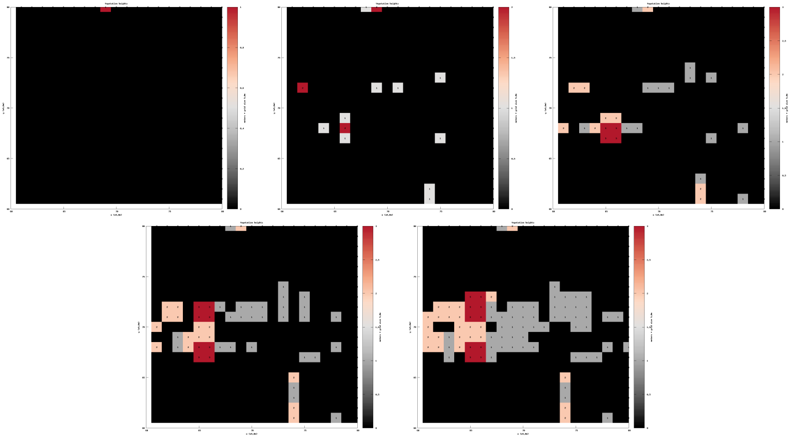
Model validations and scenarios using City of Melbourne, George and Gipps St datasets

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



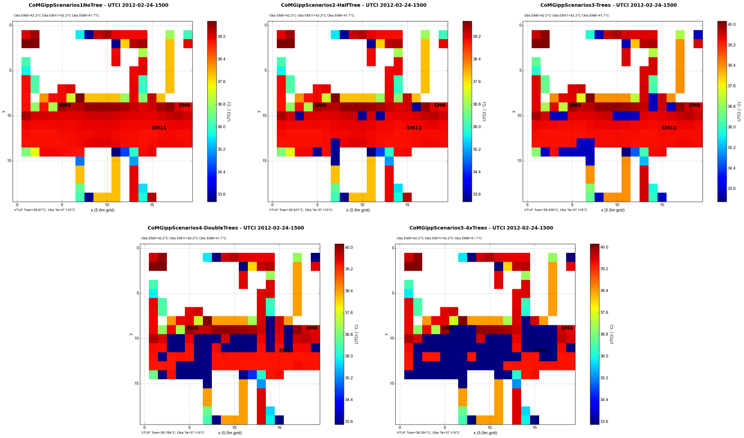
Validation against 4 and 3 observation stations located on street

City of Melbourne Gipps St Scenarios-tree configurations



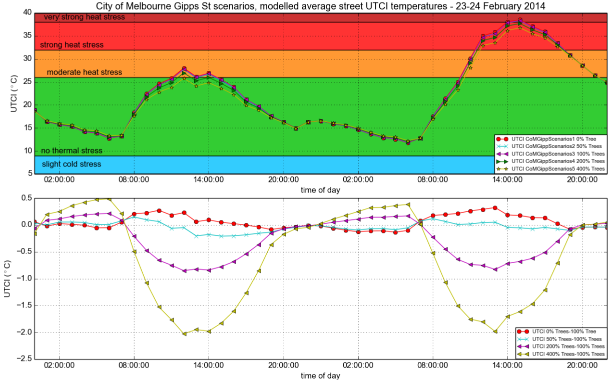
- 5 scenarios of zero trees, half trees, existing Gipps St tree canopy cover, double trees, and 4x trees.

City of Melbourne Gipps St Scenarios-UTCI at 0 meters



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

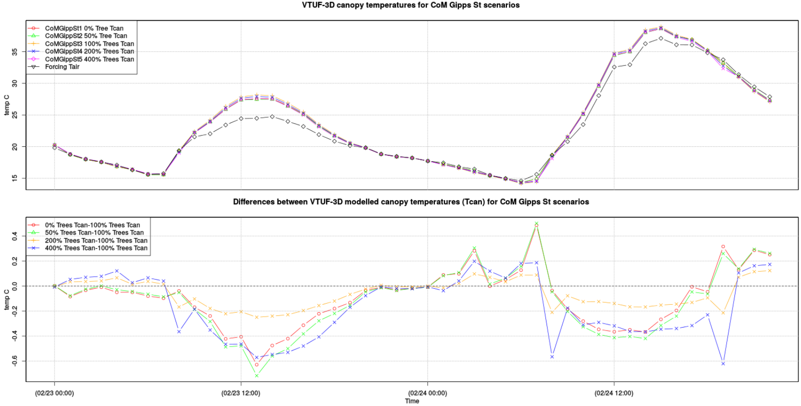
City of Melbourne Gipps St Scenarios-UTCI differences between scenarios



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

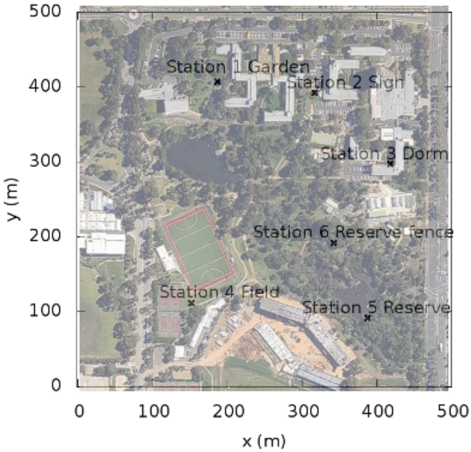
City of Melbourne Gipps St Scenarios-Canopy temperatures

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



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

Outline



1-"Garden"-Grassy area, moderate tree cover

2-"Sign"-in car park, some tree cover, asphalt surfaces

3-"Dorm"-Grassy area nested in corner of building

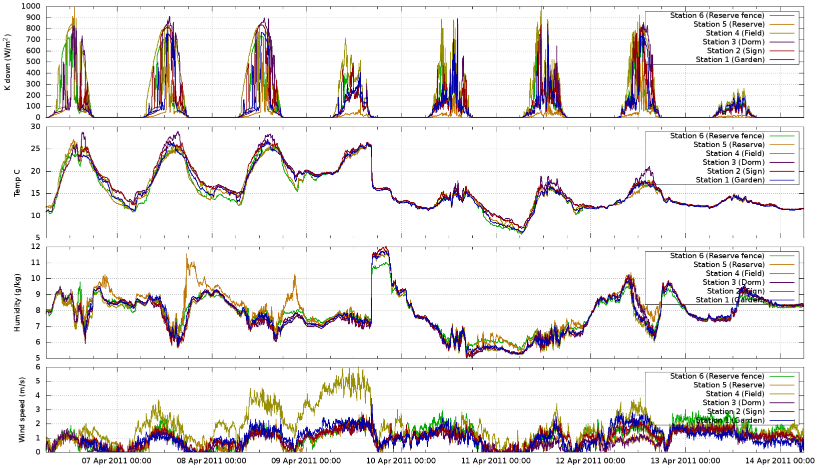
4-"Field"-Grassy hill, no tree cover

5-"Reserve"-Under tree cover by pond, dirt understory area

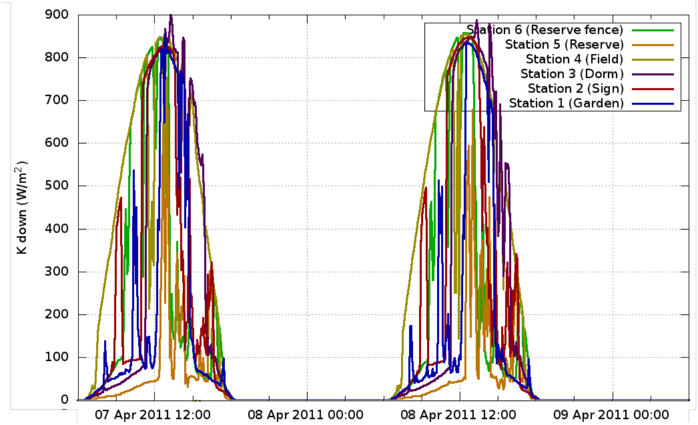
6-"Fence"-In sloped grassy area on edge of reserve area under moderate tree cover

(Nice, 2011)

Observation data - K (shortwave) down, temperature, humidity, wind speed for study site 7-14 April 2011

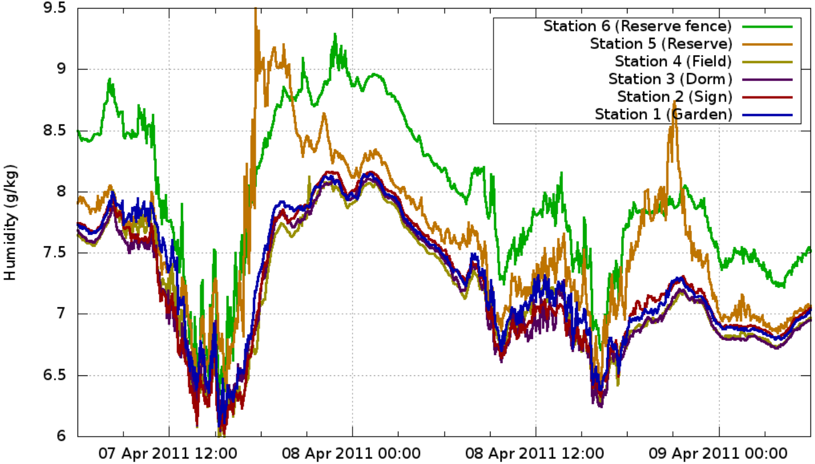


Observation data - K (shortwave) down, 7-8 April 2011



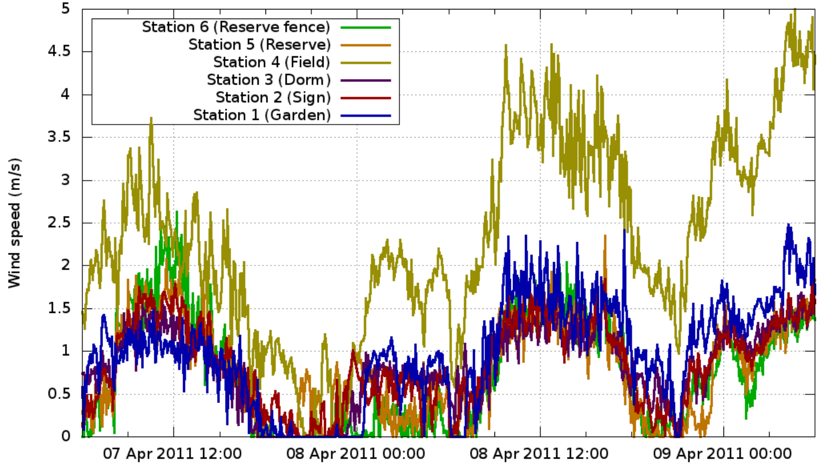
Highest at "Field", 1/2 those levels at "Garden", 1/3 at "Reserve Fence", 1/4 at "Sign" and "Dorm", 1/6 at "Reserve"

Observation data - humidity, 7-8 April 2011



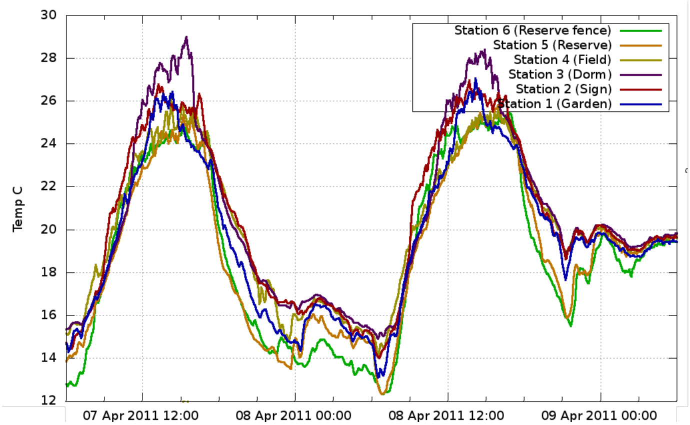
"Reserve" and "Reserve Fence" consistently higher than other sites

Observation data - wind speed, 7-8 April 2011



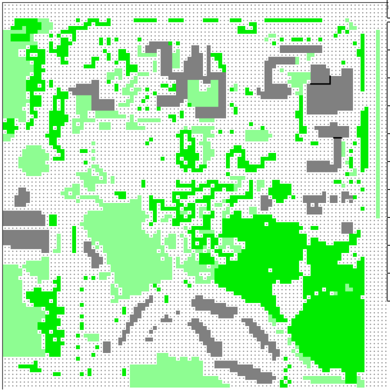
Varied 0-2 m/s except "Field" peaking at 6 m/s, 1st evening calming, pre-dawn wind, 2nd day "Field" increase

Observation data - temperature, 7-8 April 2011



Daytime 4.9°C difference between "Dorm" and "Reserve Fence", other sites vary by 2-3°C, Night time 3.2°C difference between "Sign" and "Reserve Fence"/"Reserve", "Reserve Fence"/"Reserve" cooled most rapidly at night

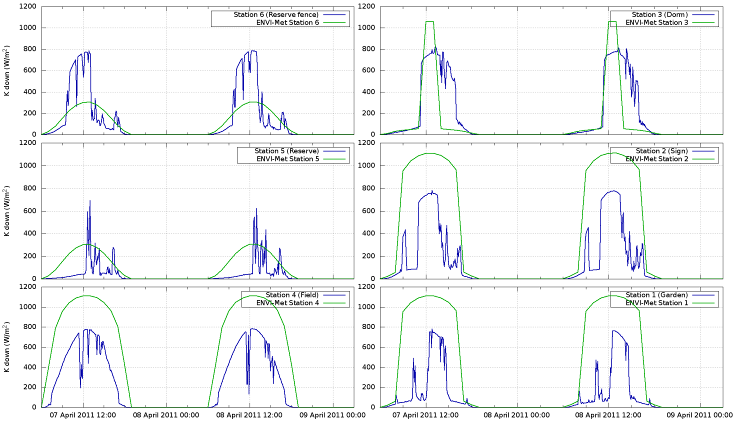
ENVI-met urban micro-climate model setup



Setting	Value
Grid size	100x100x20
Grid resolution	5 metres
Nesting grids	9
Latitude and longitude	144.58 and -37.49
Initial wind direction	north (0°)
Initial wind speed	2 m/s
Initial temperature	288K
Soil moisture	30/30/50%
Simulation run dates	5-10 April 2011
Save state	60 minutes

ENVI-met v3 set-up values

Comparison of K down (incoming shortwave radiation) of observation sites vs. ENVI-met model results, 7-8 April 2011



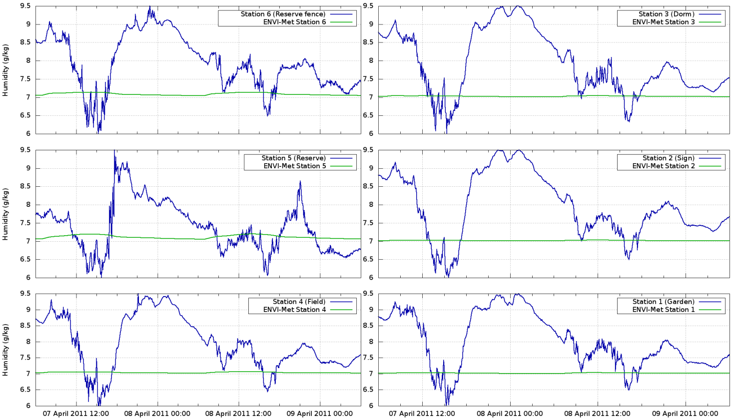
Shortwave radiation overstated, lacks variation seen in observations

Accumulated shortwave radiation (in $MJ/m^2/day$) received over 7-8 April 2011, observations vs. ENVI-met

Sites	ENVI-met	Observed
Garden	30.7	7.7
Sign	30.6	11.2
Dorm	8.9	12.6
Field	38.6	18.1
Reserve	7.6	3.0
Reserve fence	7.6	9.3

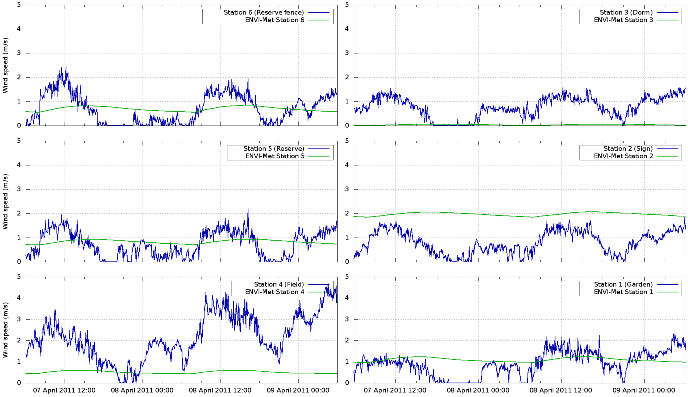
Shortwave radiation overstated, in some cases 2-3x

Comparison of humidity (g/kg) of observation sites vs. ENVI-met model results, 7-8 April 2011



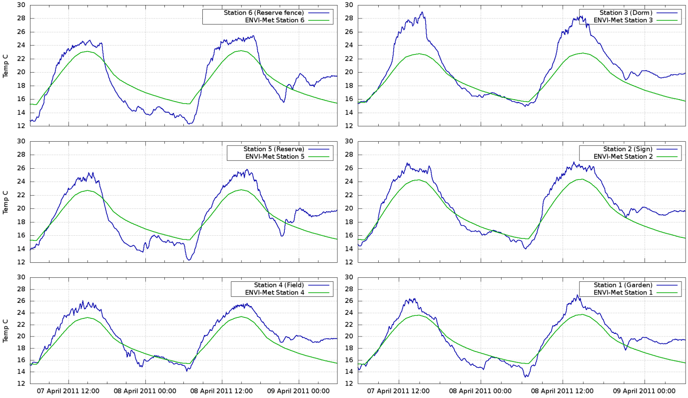
Humidity predictions lacks variation seen in observations

Comparison of wind speed of observation sites vs. ENVI-met model results, 7-8 April 2011



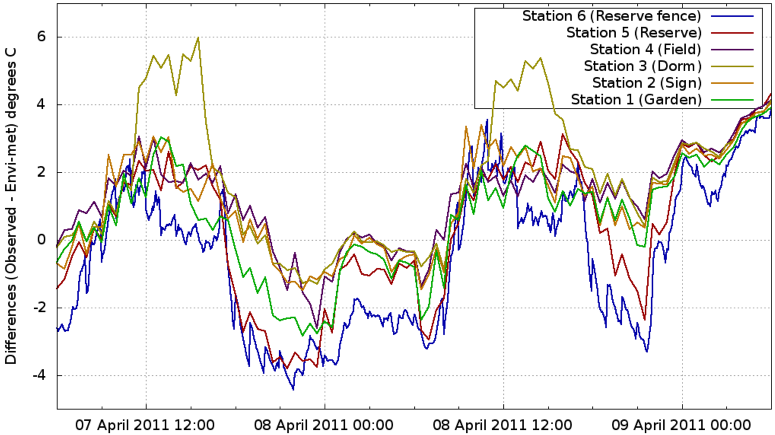
Static wind speeds, model misses calming winds in evening, rising winds through night, temperature variation greatest during calm winds

Comparison of temperature of observation sites vs. ENVI-met model results, 7-8 April 2011



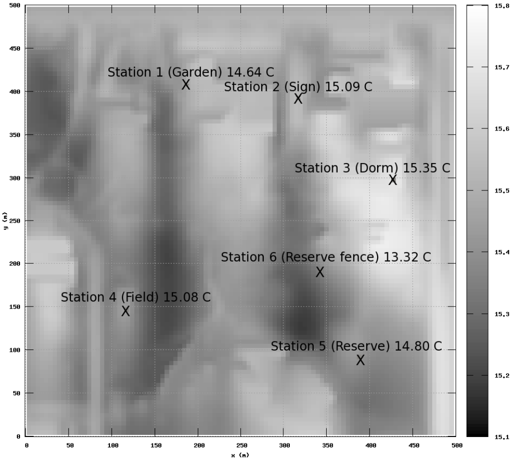
Under-prediction of daytime temperatures, slow to heat up, over-predicts night-time temperatures, slow to cool down

Differences in temperature between observation sites and ENVI-met model results, 7-8 April 2011



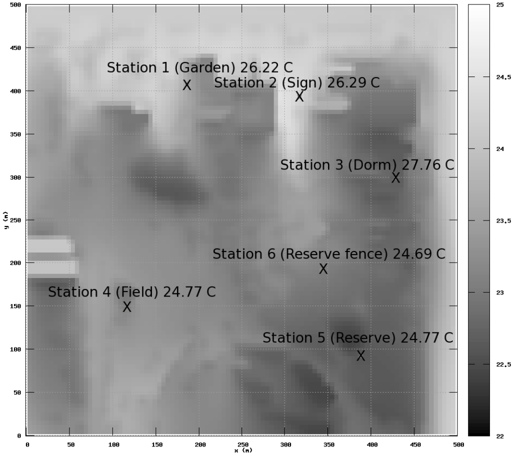
Divergences of +6°C to -4°C, in some cases, and +2°C to -2°C in all cases.

Temperature (in °C) results for ENVI-met model run with observational site data points, 8 April 2011 6:00 am.



15.1°C to 15.8°C, compared to the observed range of 13.3°C to 15.4°C but with some reasonable predictions of broad features

Temperature (in °C) results for ENVI-met model run with observational site data points, 8 April 2011 2:00 pm.



22°C to 25°C. compared to the observed range 24.7°C to 27.8°C but with some reasonable predictions of broad features

Observations conclusions

- Daytime variations of up to 4.9°C between "urban" and "parkland" areas
- General daytime variations of 2-3°C
- Night time 3.2°C variations between "urban" and "parkland" areas
- "Parkland" areas cooled most rapidly at night
- Humidity consistently higher in "parkland" areas
- Higher wind speeds moderated temperatures in highly solar exposed "Field" site
- Sheltered "Dorm" site allowed daytime temperatures to build
- Rising and falling winds created temperature variations over day and nights
- The variations found could be useful in addressing UHI effects

Model conclusions

- Simplistic modelling of canopy leads to inaccurate shortwave predictions
- ENVI-met hampered by static and inaccurate meteorological predictions missing variations due to mechanical mixing, i.e. cooling of highly solar and wind exposed "Field" site
- Observed sharp drops in temperature after dusk and slight rises before dawn not predicted by model
- Warming and cooling lags behind observed values
- Maximum and minimum values under-predicted
- Edge cases ("Dorm", "Reserve") not predicted accurately
- ENVI-met predicts large scale features, but given the resolution of observed data (6 observation sites), it isn't possible to determine if they are accurate
- Work to be done on future ENVI-met versions (and other urban micro-climate models)

Suggested reading

- Grimmond et al. (2010) The International Urban Energy Balance Models Comparison Project: First results from Phase 1 Journal of Applied Meteorology & Climatology, 49, 1268-92, doi: 10.1175/2010JAMC2354.1
- Grimmond et al. (2011) Initial Results from Phase 2 of the International Urban Energy Balance Comparison Project, International Journal of Climatology 31:244-272 DOI: 10.1002/joc.2227

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