URBAN ALBEDO

DIGITAL TOOLS FOR URBAN RESILIENCE AND GROWTH

Monday 15th October, London Living Room, Green GB week

Kent School of Architecture | Centre for Architecture & Sustainable Environment (CASE)

Brunel University London

Loughborough University

EPSRC Engineering and Physical Sciences Research Council

GREATER LONDON AUTHORITY

LONDON climate change PARTNERSHIP

Agenda

11:00 Chair's welcome - *Colin Pullan UDG*

11:20 London's heat risk in a changing climate - *Kristen Guida, LCCP*

11:30 Urban albedo - state of knowledge and project overview

12:00 Insights from practice panel
- The Concrete Centre
- Fosters + Partners
- SWECO
- IESVE
- CIBSE Resilient Cities

12:30 Chaired discussion

13:00 Lunch

13:50 Introduction to session

13:55 Scoping the next generation of urban albedo tools – *table work*

14.55 Reporting back

15:15 Coffee break

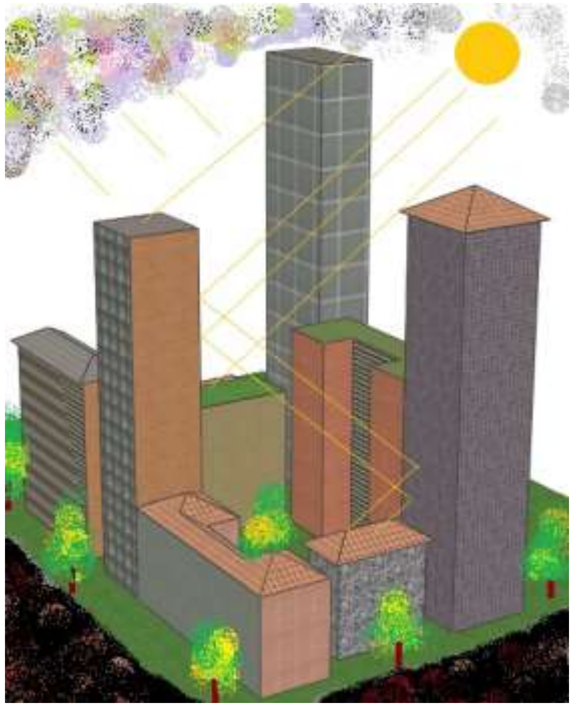
15:30 Emerging themes

15:40 Chaired discussion

15:50 Chair's summary and next steps

16:00 Close

Urban Albedo Computation in high latitude locations: an experimental approach



Prof. Marialena Nikolopoulou (PI)
Dr Giridharan Renganathan (CoI)
Dr Richard Watkins (CoI)
Dr Alkis Kotopouleas (PDRA)

Prof. Maria Kolokotroni (CoI)
Dr Agnese Salvati (PDRA)

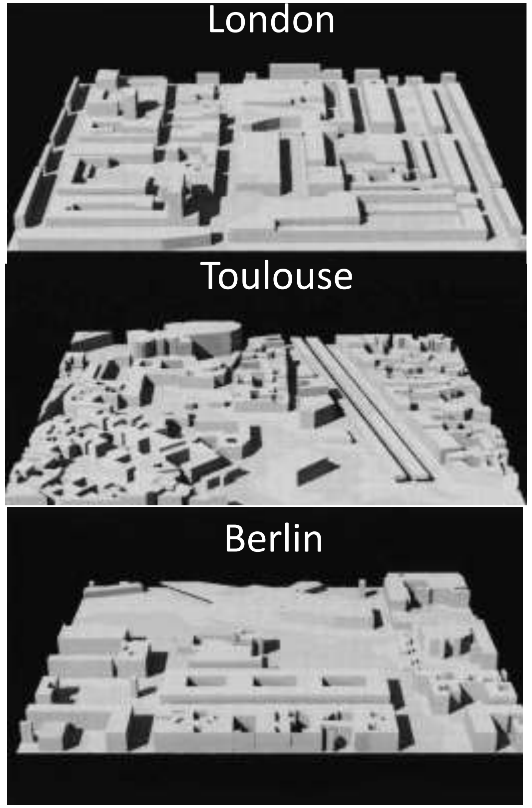
Prof. Bala Vaidhyanathan (CoI)
Dr Aashu Anshuman (PDRA)

Project aims & objectives

- Incorporate *accurate* calculation and prediction of urban albedo in the planning and design process
- Investigate experimentally the impact of urban fabric on urban albedo, using on London as a case-study
- Develop a catalogue of urban albedo for various materials and geometrical configurations
- Develop an urban albedo calculator, an empirical model to predict changes in urban albedo in relation to changes in urban fabric and solar altitude

3-year project (2017-2020)

Radiation absorption and urban texture



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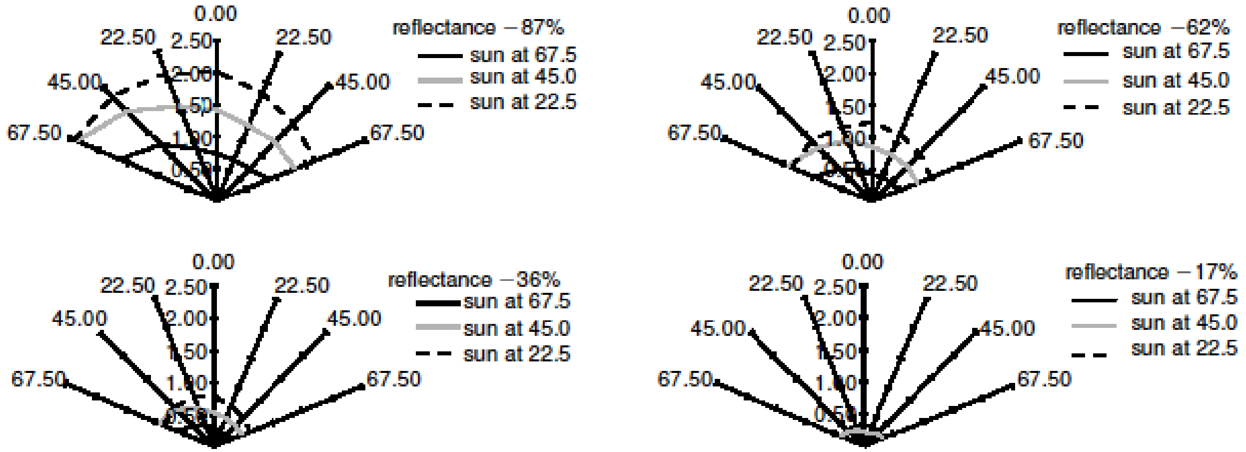
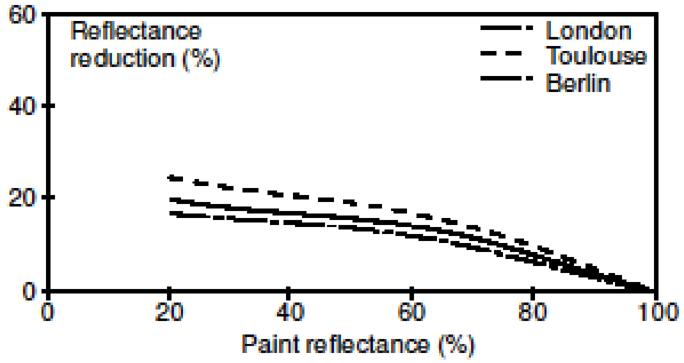


Measured distribution of reflected light for the London model for three sun-angles and four different paint reflectances



Reduction in hemispherical reflectance compared with flat plane

Project tasks

Task 1: Urban survey and 3D scanning

Task 2: Experimental model – scale of 1:10

Task 3: Weathering

Task 4: Urban albedo calculator

Task 5: Urban modelling and simulation

Task 6: Dissemination and outreach

Prof. Marialena Nikolopoulou
Dr Giridharan Renganathan
Dr Richard Watkins
Dr Alkis Kotopouleas
Muhammed Yeninarcilar

Task 1
Urban survey and 3D scanning

Field surveys

- 50 locations (100x100m) within the Greater London area
- Collection of information on building block typology, canyon geometry, surface characteristics and ground level surface albedo.
- Starting point:
  - ✓80 locations in Greater London studied in terms of UHI in 2002[1]
- Survey locations to include:
  - ✓Urban and semi-urban areas
  - ✓Commercial, residential and mixed-use areas
  - ✓Variation in geometry and building materials
  - ✓Areas within or close to Opportunity Areas[2]
  - ✓Areas with higher average surface temperature profile[3], as modelled with LondUM[4] for the period 26 May 2006 - 31 Aug 2006.

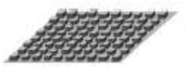
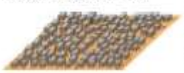
[1] Richard Watkins, The impact of the urban environment on the energy used for cooling buildings, PhD Thesis, Brunel University, June 2002
[2] https://www.london.gov.uk/what-we-do/planning/implementing-london-plan/opportunity-areas/opportunity-areas
[3] https://data.london.gov.uk/dataset/london-s-urban-heat-island
[4] Jonathon Taylor, UCL Institute for Environmental Design and Engineering

Survey protocol for characterisation of urban geometry

- The study uses the local climate zone (LCZ) system developed by Stewart & Oke[1]
- New sub-zones will be developed for cases that are not represented in the existing LCZs

Local climate zone (LCZ)	Sky view factor[a]	Aspect ratio[b]	Building surface fraction[c]	Impervious surface fraction[d]	Per sur frac
LCZ 1 *Compact high-rise*	0.2–0.4	> 2	40–60	40–60	<
LCZ 2 *Compact midrise*	0.3–0.6	0.75–2	40–70	30–50	<
LCZ 3 *Compact low-rise*	0.2–0.6	0.75–1.5	40–70	20–50	<
LCZ 4 *Open high-rise*	0.5–0.7	0.75–1.25	20–40	30–40	30
LCZ 5 *Open midrise*	0.5–0.8	0.3–0.75	20–40	30–50	20
LCZ 6 *Open low-rise*	0.6–0.9	0.3–0.75	20–40	20–50	30
LCZ 7 *Lightweight low-rise*	0.2–0.5	1–2	60–90	< 20	<
LCZ 8 *Large low-rise*	>0.7	0.1–0.3	30–50	40–50	<
LCZ 9 *Sparsely built*	> 0.8	0.1–0.25	10–20	< 20	60
LCZ 10 *Heavy industry*	0.6–0.9	0.2–0.5	20–30	20–40	40
LCZ A *Dense trees*	<0.4	>1	<10	<10	>
LCZ B *Scattered trees*	0.5–0.8	0.25–0.75	<10	<10	>
LCZ C *Bush, scrub*	0.7–0.9	0.25–1.0	<10	<10	>
LCZ D *Low plants*	>0.9	<0.1	<10	<10	>
LCZ E *Bare rock or paved*	>0.9	<0.1	<10	>90	<
LCZ F *Bare soil or sand*	>0.9	<0.1	<10	<10	>
LCZ G *Water*	>0.9	<0.1	<10	<10	>

[a] Ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemi
[b] Mean height-to-width ratio of street canyons (LCZs 1–7), building spacing (LCZs 8–10), and tree
[c] Ratio of building plan area to total plan area (%)
[d] Ratio of impervious plan area (paved, rock) to total plan area (%)
[e] Ratio of pervious plan area (bare soil, vegetation, water) to total plan area (%)
[f] Geometric average of building heights (LCZs 1–10) and tree/plant heights (LCZs A–F) (m)
[g] Davenport et al.'s (2000) classification of effective terrain roughness (z_0) for city and country landsca

Built types		Definition
1. Compact high-rise		Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.
2. Compact midrise		Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.
3. Compact low-rise		Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.
4. Open high-rise		Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.
5. Open midrise		Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.
6. Open low-rise		Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.
7. Lightweight low-rise		Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).
8. Large low-rise		Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.
9. Sparsely built		Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).
10. Heavy industry		Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.

Land cover types		Definition
A. Dense trees		Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
B. Scattered trees		Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
C. Bush, scrub		Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
D. Low plants		Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
E. Bare rock or paved		Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.
F. Bare soil or sand		Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
G. Water		Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.

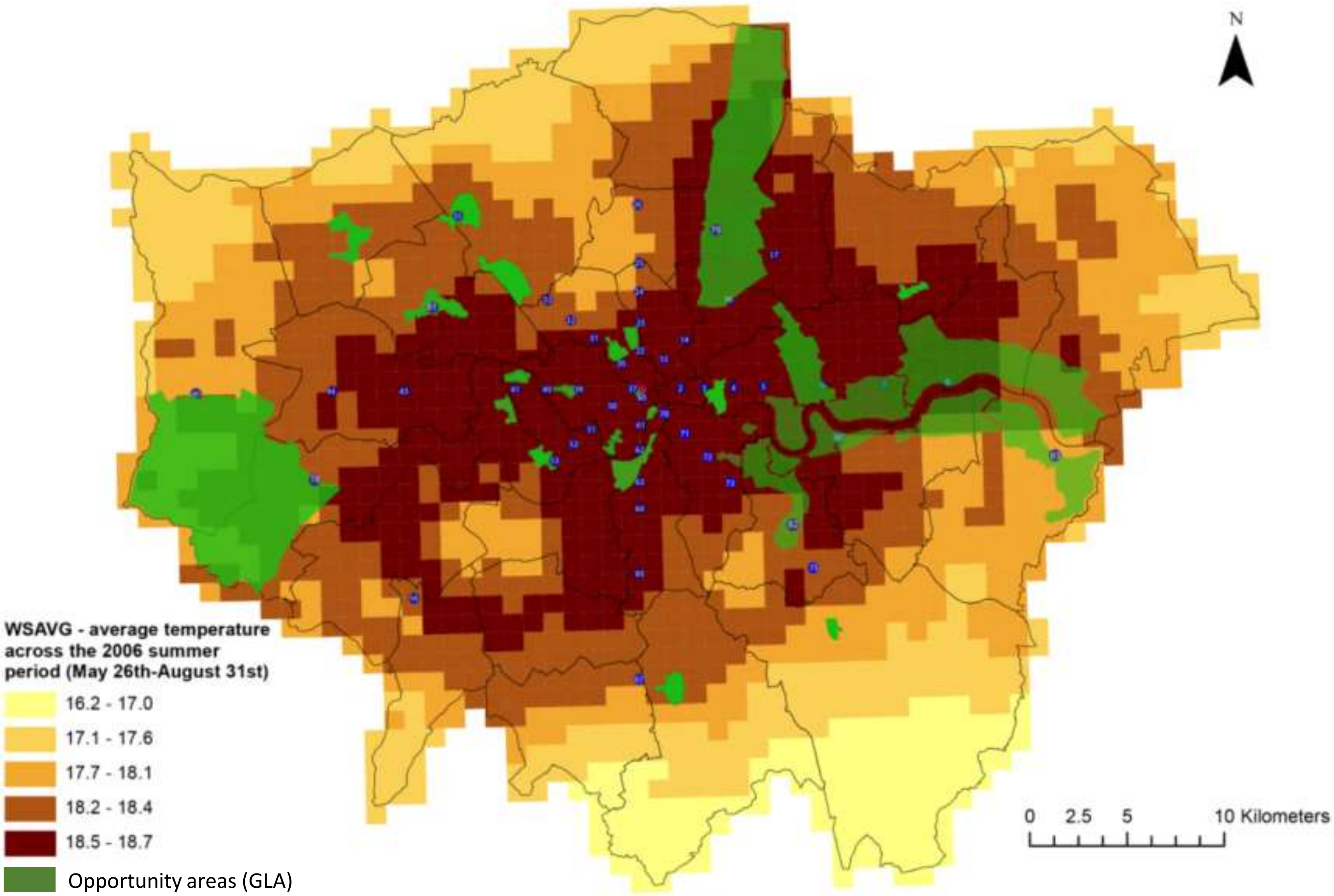
VARIABLE LAND COVER PROPERTIES

Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.

b. bare trees	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.
s. snow cover	Snow cover >10 cm in depth. Low admittance. High albedo.
d. dry ground	Parched soil. Low admittance. Large Bowen ratio. Increased albedo.
w. wet ground	Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

[1]ID Stewart & TR Oke, Local Climatic Zones for Urban Temperature Studies, Journal of American Meteorological Society, Dec 2012.

50 survey locations



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Three areas to be modelled

Selection criteria based on surveys:

- ✓ Residential, commercial and mixed-use area
- ✓ Representative building height, materials and façade finish
- ✓ Buildability

Stanley Terrace (residential)

Bishopsgate (commercial)

Mina Road (mixed use)

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Field surveys (residential)

- Block typology, canyon geometry, surface characteristics, facade elements & size of openings (windows size estimated based on no. of bricks)
- Ground level surface albedo
- Ambient air temperature, RH & wind speed

Stanley Terrace

Stones End Str.

Upper Ground

Field surveys (residential)

- Brickwork: predominantly buff lime at Stanley Terrace and combination of red and lime bricks at Upper Ground
- Street and pavement width ranges:
  - 8.25-8.40m and 1.75-2.10m in Stanley Terrace case study
  - 4.31-7.35m and 0.36-1.80m in Upper Ground case study
- Pavement height varied between 0.09m and 0.15m → can be ignored in model building
- Albedo measurements were taken in the middle of street gorges.

Descriptive statistics of incident & reflected irradiation and albedo

		Incident (W/m²)	Reflected (W/m²)	Albedo
Stanley Terrace (party cloudy conditions)	**Avg**	**322**	**24**	**0.07**
	Min	128	8	0.03
	Max	875	80	0.10
	SD	215	19	0.01
Upper Ground (clear sky conditions)	**Avg**	**754**	**66**	**0.09**
	Min	111	14	0.07
	Max	816	88	0.13
	SD	166	18	0.02

Task 2

Experimental model

Experimental site

- 20x20m tarmac field located in the UKC campus, Canterbury
- Site preparation
  - ✓ Fencing
  - ✓ Shed to house data logger and provide materials storage

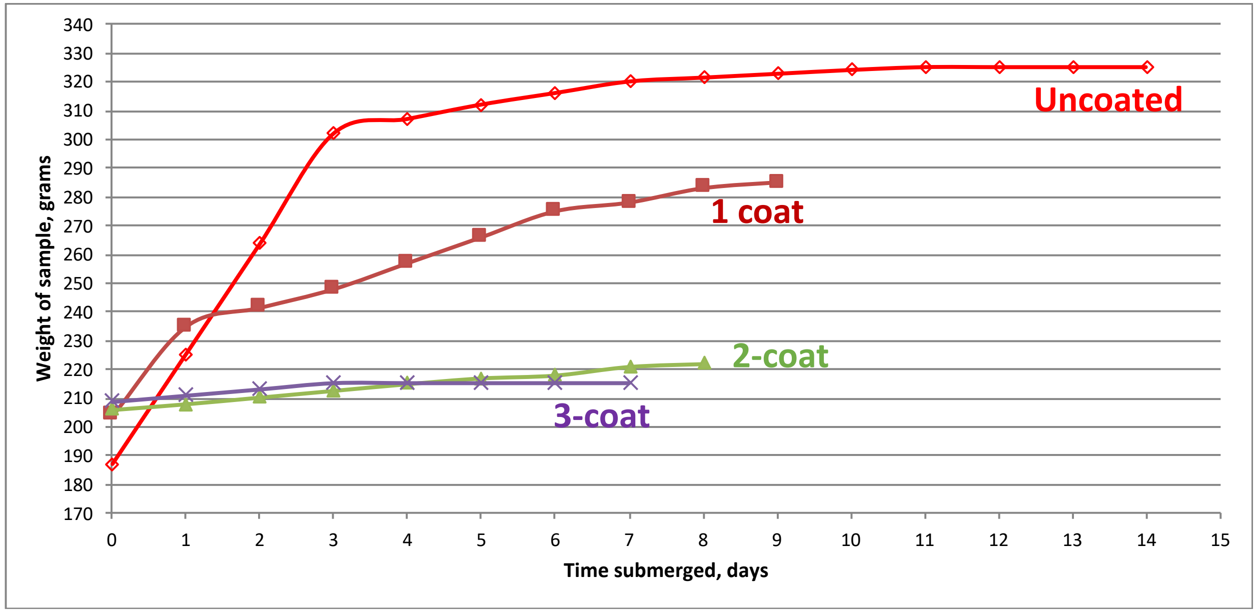
Experimental model – Inceptive concept

- The physical model will be built to 1:10 scale at the UKC campus using an area of 5m radius
- Use of plywood boxes to allow uncomplicated adjustment of model dimensions
- Materials to be attached onto the boxes.
- The initial concept for 300 x 300 x 300mm boxes, 11 mm thick, made in the University workshop, succeeded the use of no nail 250 x 250 x 250mm boxes, 4mm thick, prefabricated and sewn together with cold rolled annealed steel.

Cost & time efficiency

Experimental model – water absorption test

- Four samples (box lids) were submerged in water to assess the absorptivity of the original plywood compared to that with 1 coat, 2 coats and 3 coats of satin yacht varnish.
- The results from this intensive test showed that at least 3 coatings are required as for the plywood to retain its original weight.



Uncoated sample: bend due to water absorption

Application of varnish

Submerged in water

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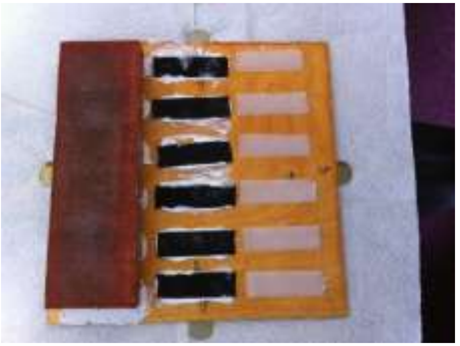
Experimental model – attaching materials test

- Tests commenced using the most common and heaviest material to be used in the model, bricks
- As it is the surface characteristics that matters, the study uses brick slips, instead of bricks. These are provided by IBSTOCK.

	building block	red brick slip	lime brick slip	brown brick slip
Height (m)	0.250	0.215	0.215	0.215
Width (m)	0.250	0.065	0.065	0.065
Depth (m)	0.250	0.018	0.018	0.018
Weight (kg)	1.385	0.709	0.600	0.812

- Different velcro-like materials and adhesives were tested to assess the strength of the bond between brick slips and plywood as well as how this evolves in water.




Experimental model – final concept

- Plywood sheets (9mm thick) are attached onto columns comprised of plywood boxes to represent the walls.
- Materials are attached onto these plywood sheets rather than boxes.
- Plywood boxes are used for structural support and adjusting the size of the buildings.

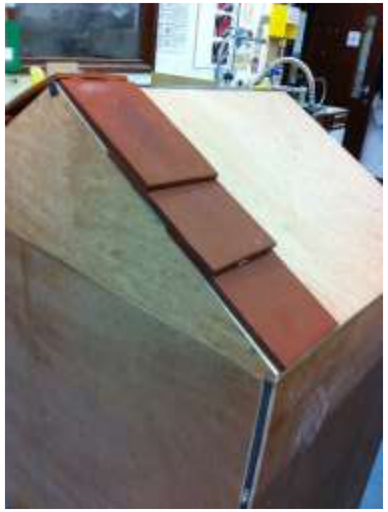





Experimental model – prototype





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Setting out the Stanley Terrace pilot model

Stanley Terrace pilot model buildings

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Model buildings development

- Made of 9mm thick plywood sheets
- Preservation against water erosion:
  - Application of 3 coats of yacht varnish
  - Sealant in gaps
- Brick slips supplied by IBSTOCK had different finish and texture than the samples tested, different adhesives had to be tested **again**.
- 1500 clay and slate character roof tiles



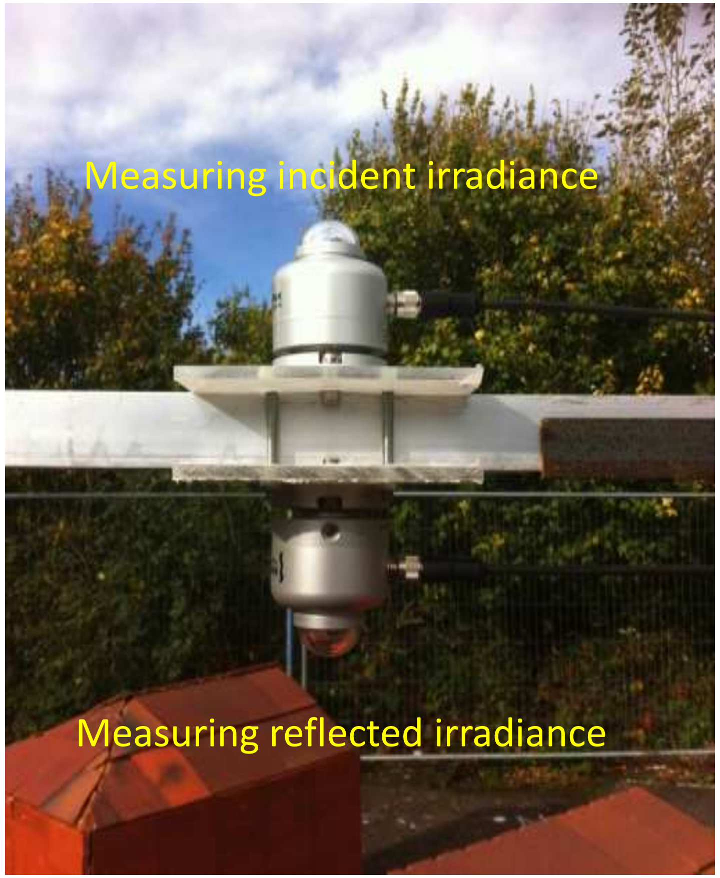


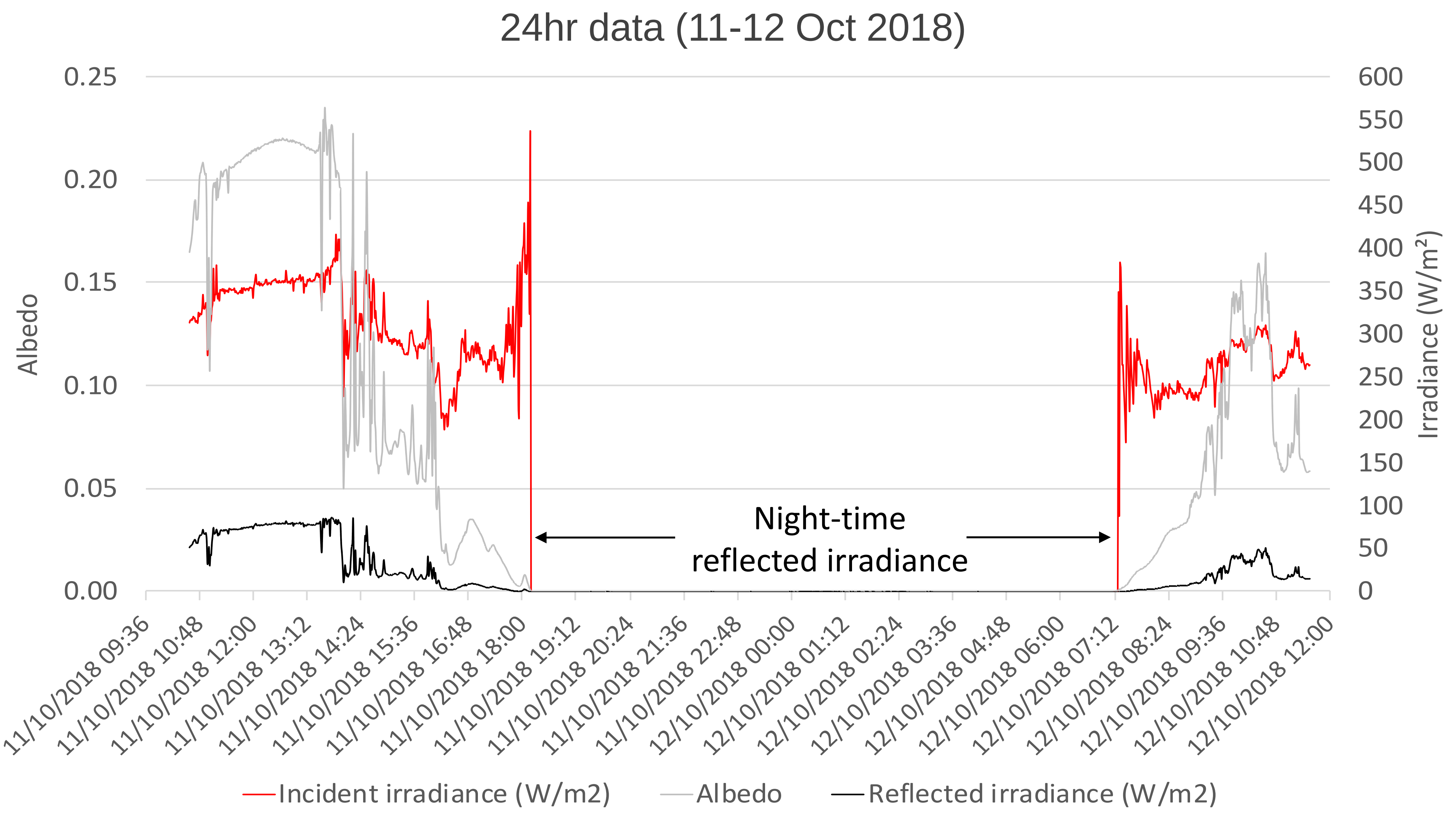


Model buildings development

Hukseflux SR05-A1 pyranometer

Pyranometers on aluminum box section forming an albedometer





Current work involves sensor sensitivity tests to determine pyranometers' response to changes (e.g. addition of materials)

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Calculating Urban Albedo

Daytime irradiance and albedo

	Average	Min	Max	Standard Dev.
Incident (W/m^2)	241.1	2.7	562.3	185.1
Reflected (W/m^2)	32.9	0.1	86.1	28.7
Albedo	0.12	0.04	0.22	0.02

As a result of the solar radiation absorbed during daytime there is an average re-emittance of 0.52 (W/m^2) at night.

Task 3

Weathering tests and Property Assessment

Urban Albedo Project: WP3 Weathering tests and Property Assessment

Prof. Bala Vaidhyanathan
RA: Aashu Anshuman
Department of Materials
School of AACME

Q-Lab Xe-1

- Xe-1 tester has been installed and commissioned.
- Ambient temperature maintained at 23 ºC.
- Specifications:
  - Insulated black panel temperature sensor
  - UV sensor – 340 nm
  - Daylight Q filter

Experimental protocol / Deliverables

Loughborough University

- Develop sample preparation techniques
- Procure materials and identify characterisation strategies
- Standards to follow – ASTM E903, ASTM G155, ISO 4892-2, ASTM F1980 among others
- Determining artificial ageing factor compared to the real world
- Generate data for use in models

Facilities for Characterisation LMCC

Facilities for Characterisation: LMCC

Electron Microscopy

Dual Beam FIB / FEGSEM

JEOL 7100

JEOL 7800

Zeiss 1530VP

Hitachi Benchtop SEM

EDS and EBSD capability

X-Ray Diffraction

Bruker D2 Phaser

Bruker D8

Philips PW17-30

Surface Analysis

X-ray photoelectron spectrometer

Auger spectroscopy

Thermal Analysis

Dilatometry

Thermogravimetric Analysis (TGA)

Differential Scanning Calorimetry (DSC)

Thermomechanical Analysis (TMA)

Wide range of advanced characterisation techniques available: Optical properties and now FIBSIMS, FIBSEM, *insitu* heating and biasing TEM, X-ray micro CT and much more.

Task 5

Urban modelling and simulation

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Urban Albedo and microclimate modelling

Professor Maria Kolokotroni

Dr Agnese Salvati

Brunel University London

Urban Albedo and microclimate modelling

Literature review indicates that UA depends on:

- Material reflectivity
- Urban geometry
  - Façade density – (UA decreases)
  - Building height – (UA decreases)
  - Roof area - (UA increases)
  - Solar zenith angle - (UA increases)

We will investigate these with the following Modelling tools

- ENVI-met for microclimate
- Dynamic Thermal Modelling for buildings internal conditions and energy use

Both to be calibrated with measurements at test sites and scale models

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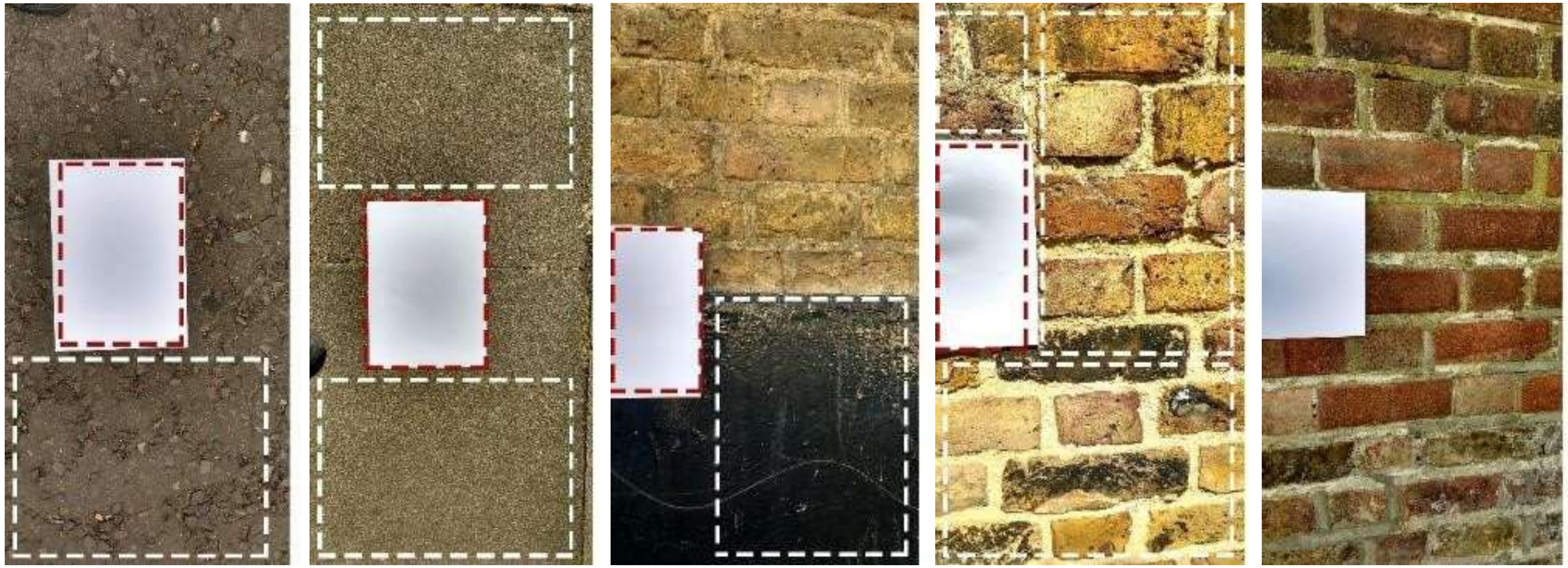
Stanley terrace : surveys and monitoring

Air temperature monitoring :
Temperature sensor on lamppost

- data from 2000 and 2007
- New monitoring will be initiated in 2018
- Radiation shield tested at Brunel

Stanley terrace : surveys and monitoring



Urban materials

Reflectivity of materials was assessed using radiation measurements and digital images processing

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ENVI-met: Microclimate model calibration

Urban geometry and material reflectivity

Streets:

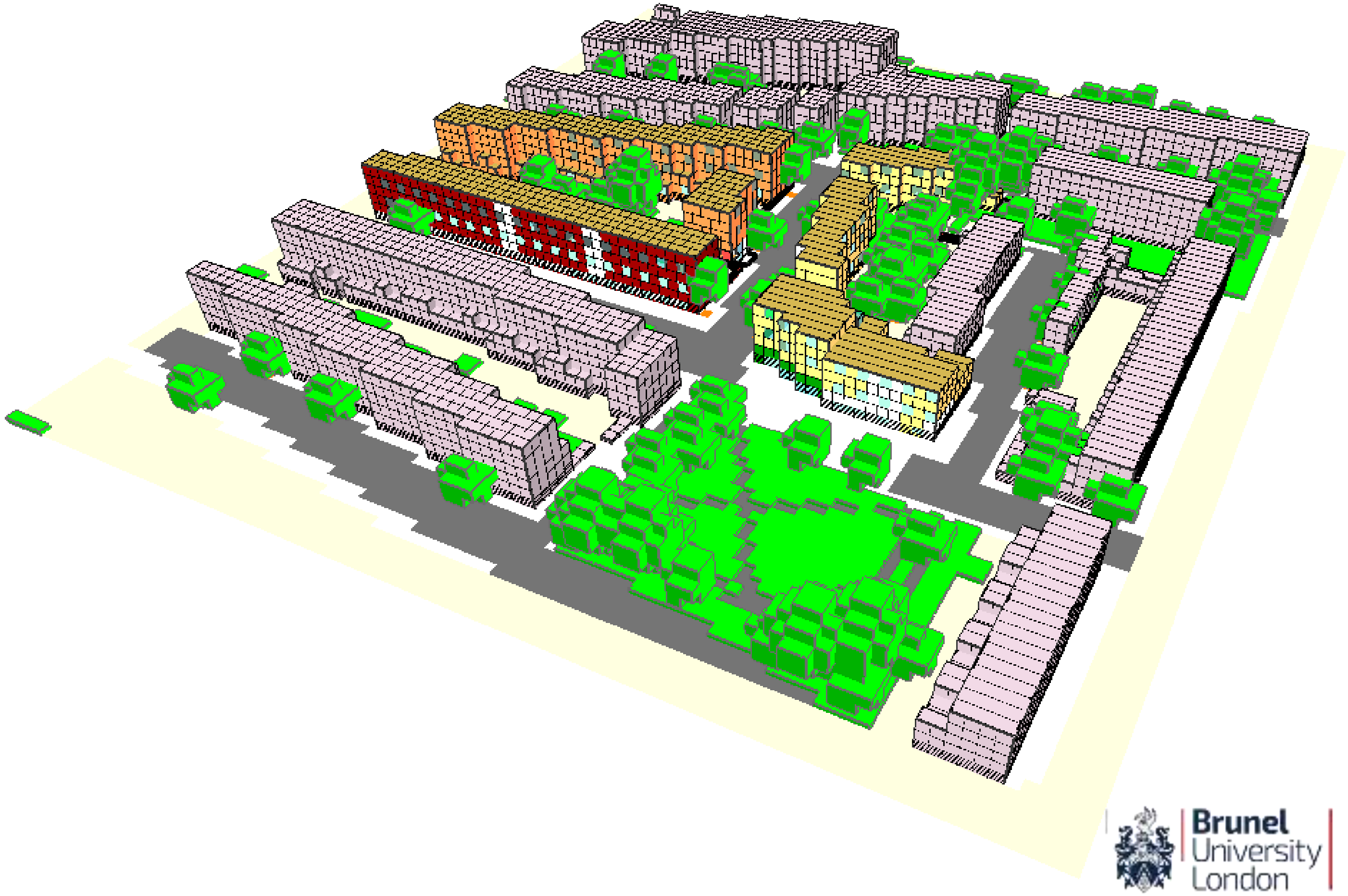
- road r=0.19
- pavement r=0.29
- Courtyards pav. r=0.26

Facades:

- yellow brick 1 r=0.39
- yellow brick 2 r = 0.42;
- red brick r= 0.24;
- black paint r= 0.08;
- dark green paint r = 12;
- white plaster r =0.7
- clear glass r =0.05

Roofs:

- tiles r= 0.5



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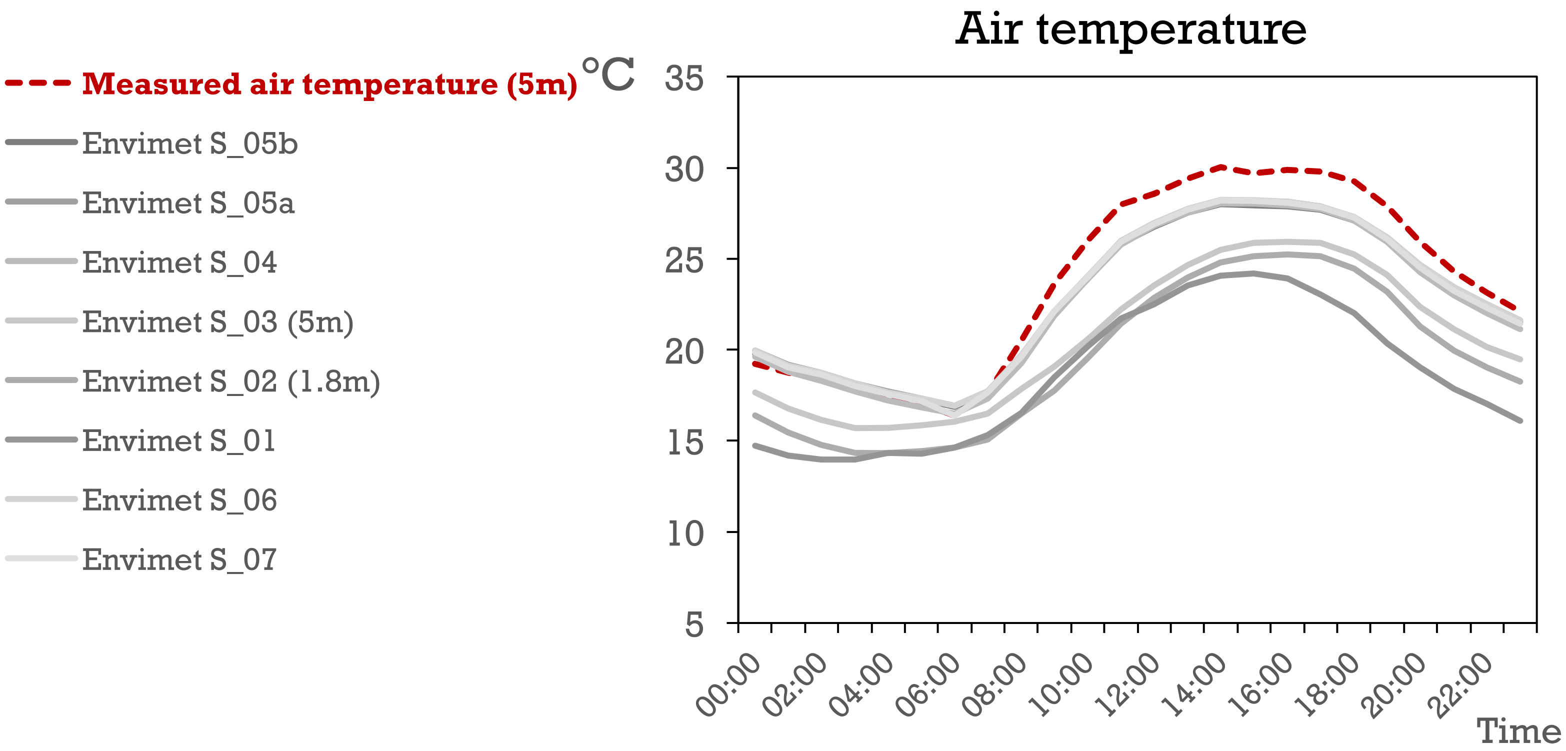
Microclimate model calibration

CFD analysis

Comparison of air temperature estimations with measurements



Model error and accuracy

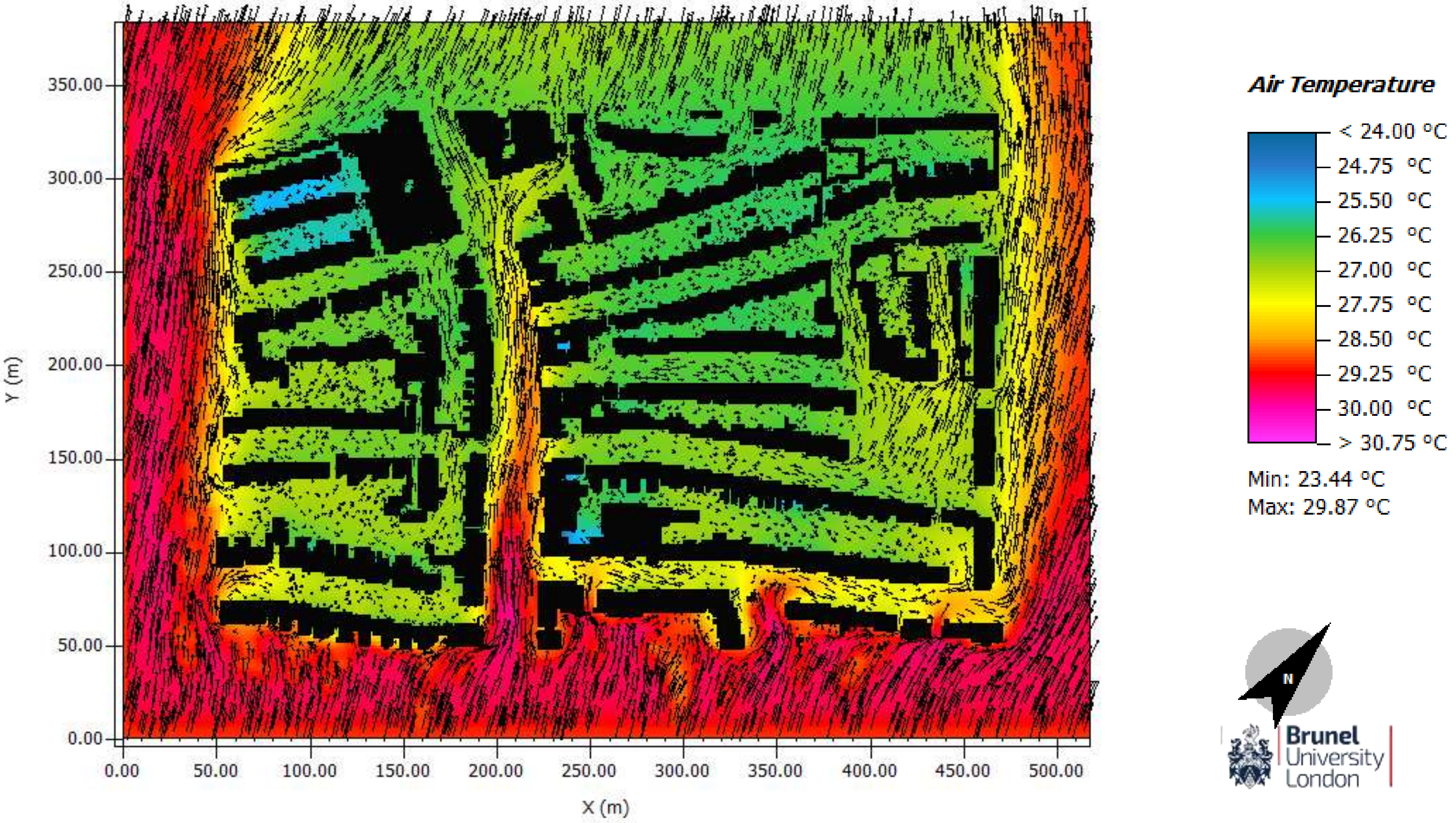
Simulation ID	RMSE	d	R squared
01	5.42	0.74	0.95
02	4.38	0.81	0.96
03	3.51	0.86	0.96
04	1.45	0.97	0.99
05a	1.29	0.98	0.99
05b	1.41	0.98	0.99
06	1.28	0.98	0.99
07	1.32	0.98	0.99

The model calibration is performed carrying out several simulations using different input parameters so as to decrease the discrepancy between estimations and actual measurements

Impact of urban albedo on microclimate

Air temperature and wind direction

12pm, 5th of August



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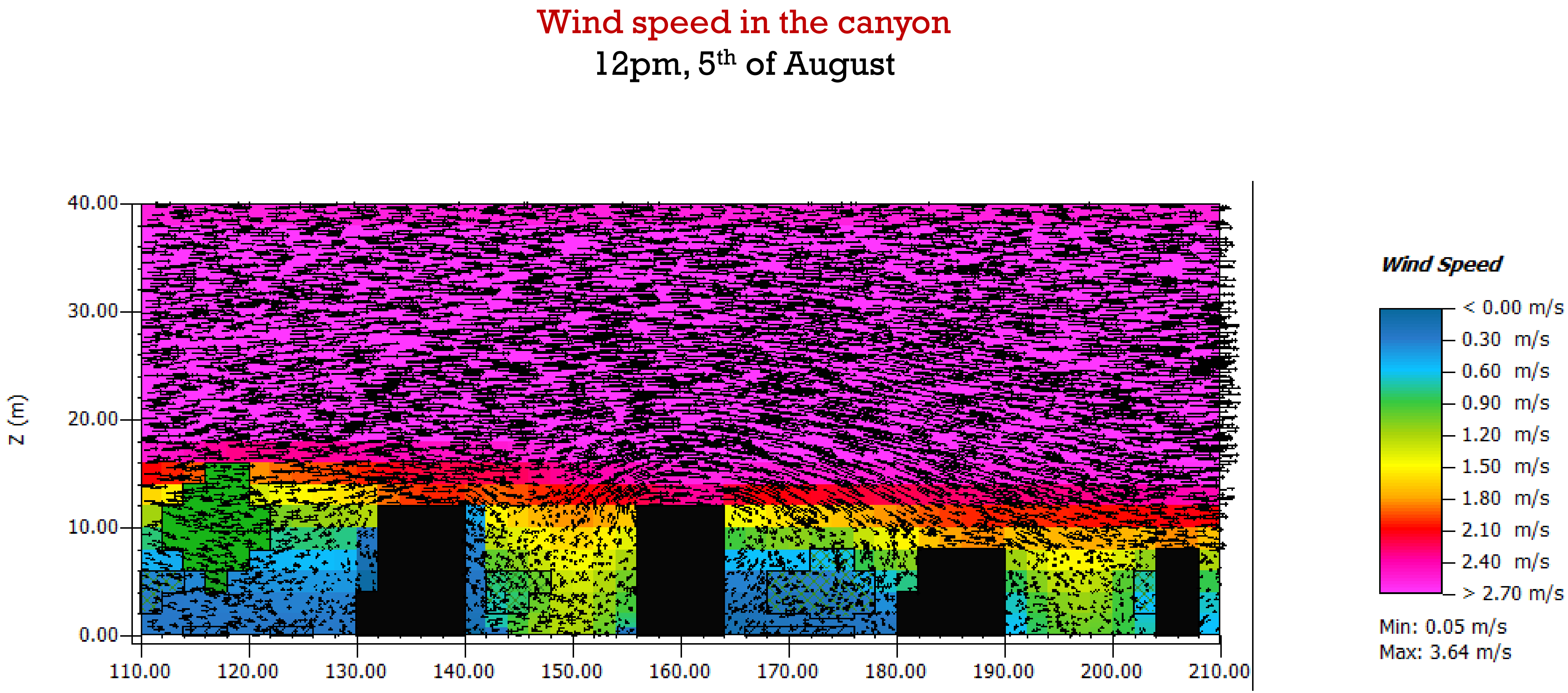
Wind speed in urban canyons



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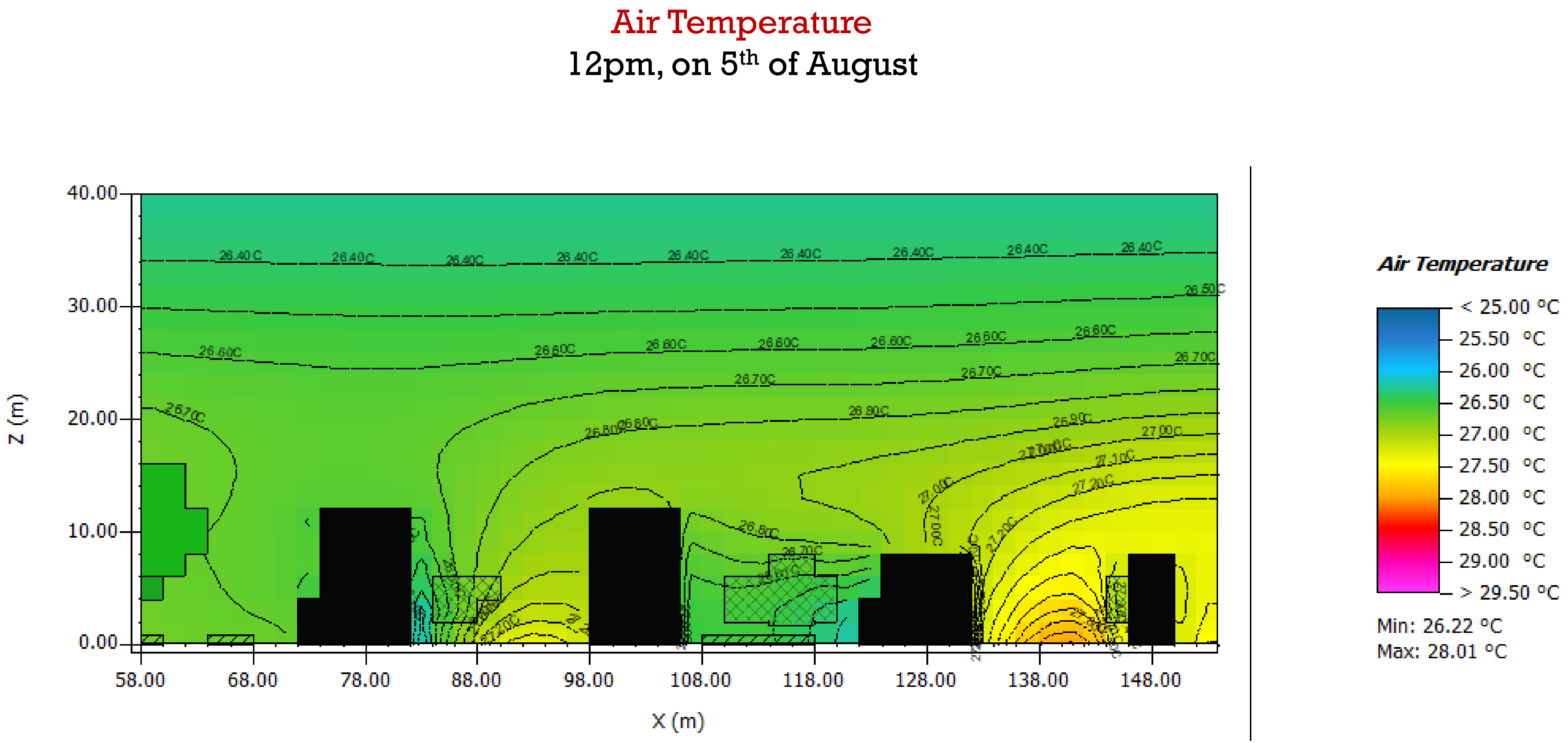
Air temperature in urban canyons



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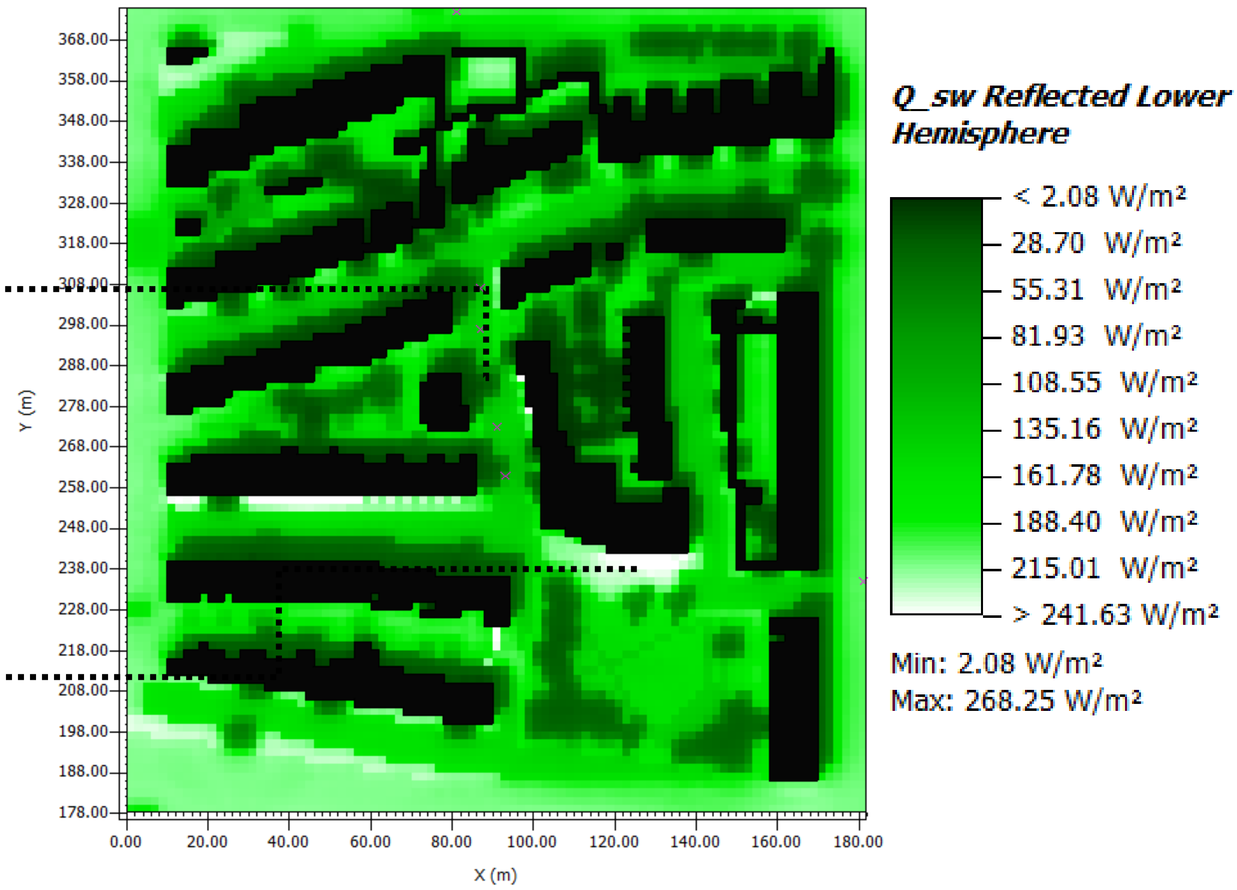
Reflection of solar radiation

Reflection of shortwave radiation
12pm, on 5th of August

Near ground level (1.4 m agl)

The decrease of reflections is due to shadows

The increase of reflections is due to higher albedo of the façade material (white plaster)



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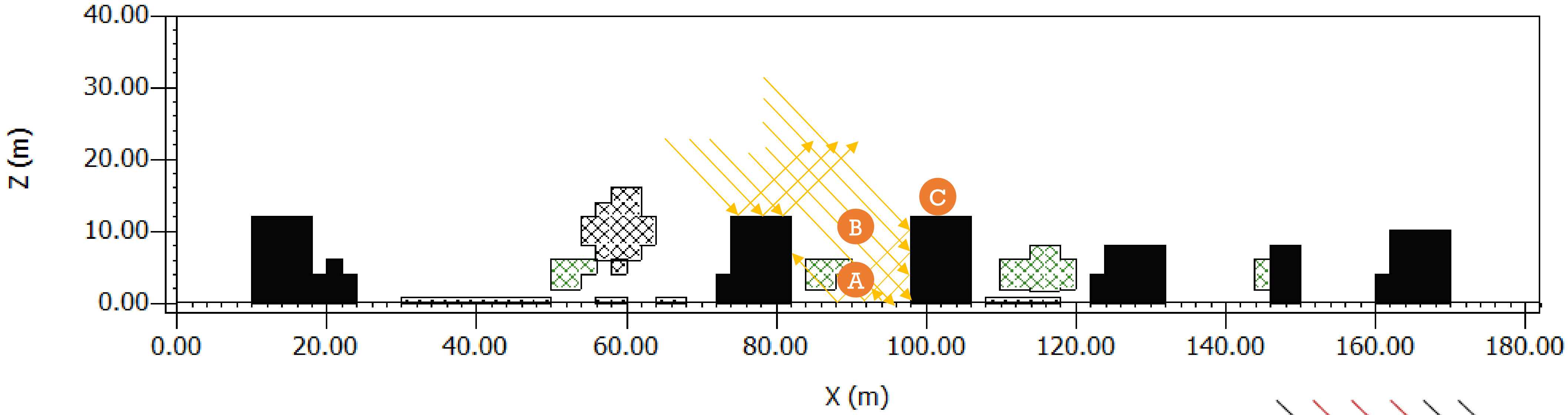
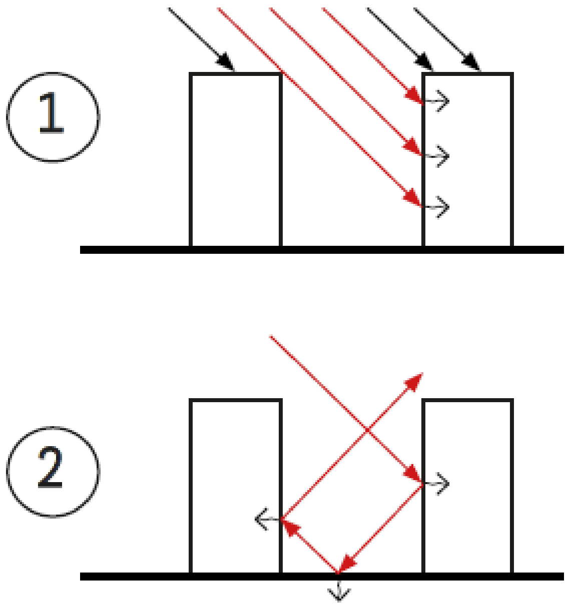
Urban albedo: Radiation budget of urban canyons



Urban geometry and **material reflectivity** modify the ratio of the outgoing to the incoming radiation upon urban surfaces:

- Obstruction of incoming solar radiation
- Multiple reflections within canyon surfaces
- Increase of radiation absorption
- Reduction of long wave radiation loss



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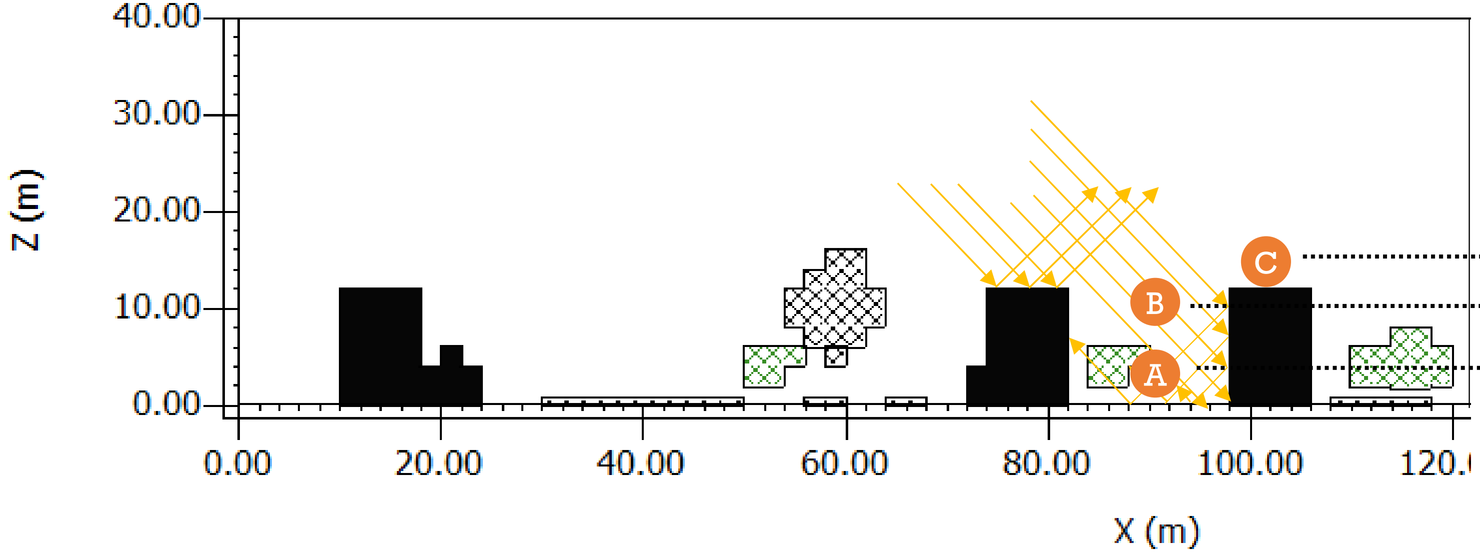
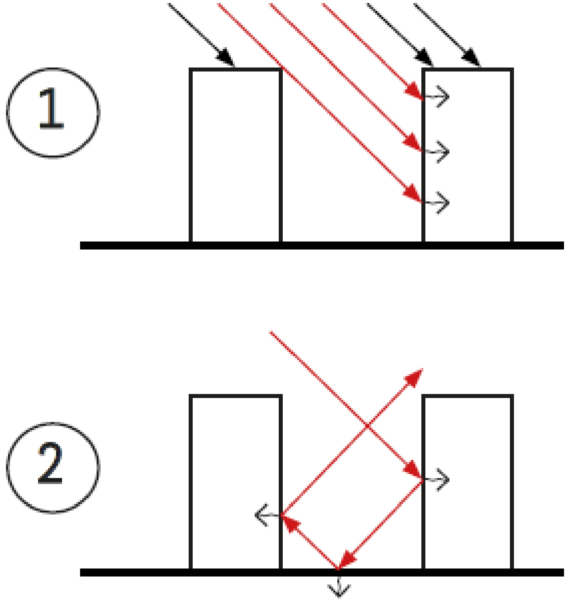
Urban albedo: Radiation budget of urban canyons



Radiation Budget
(Outgoing to incoming radiation)

~ 0.6
~ 0.05
0.2 ~ 0.4

- Minimum in B, because almost all incoming radiation is trapped in multiple reflections
- Maximum in C, because at roof level radiation is reflected toward the sky
- Variable at street level, depending on shadows and materials



Inside Buildings

- We will use ENVI-met outputs as local microclimatic inputs to DTM to accurately predict internal thermal conditions and energy consumption and **to investigate how urban albedo changes can improve performance.**

- This will feed to Urban Albedo Calculator development and how to link it with microclimate and DTM models.

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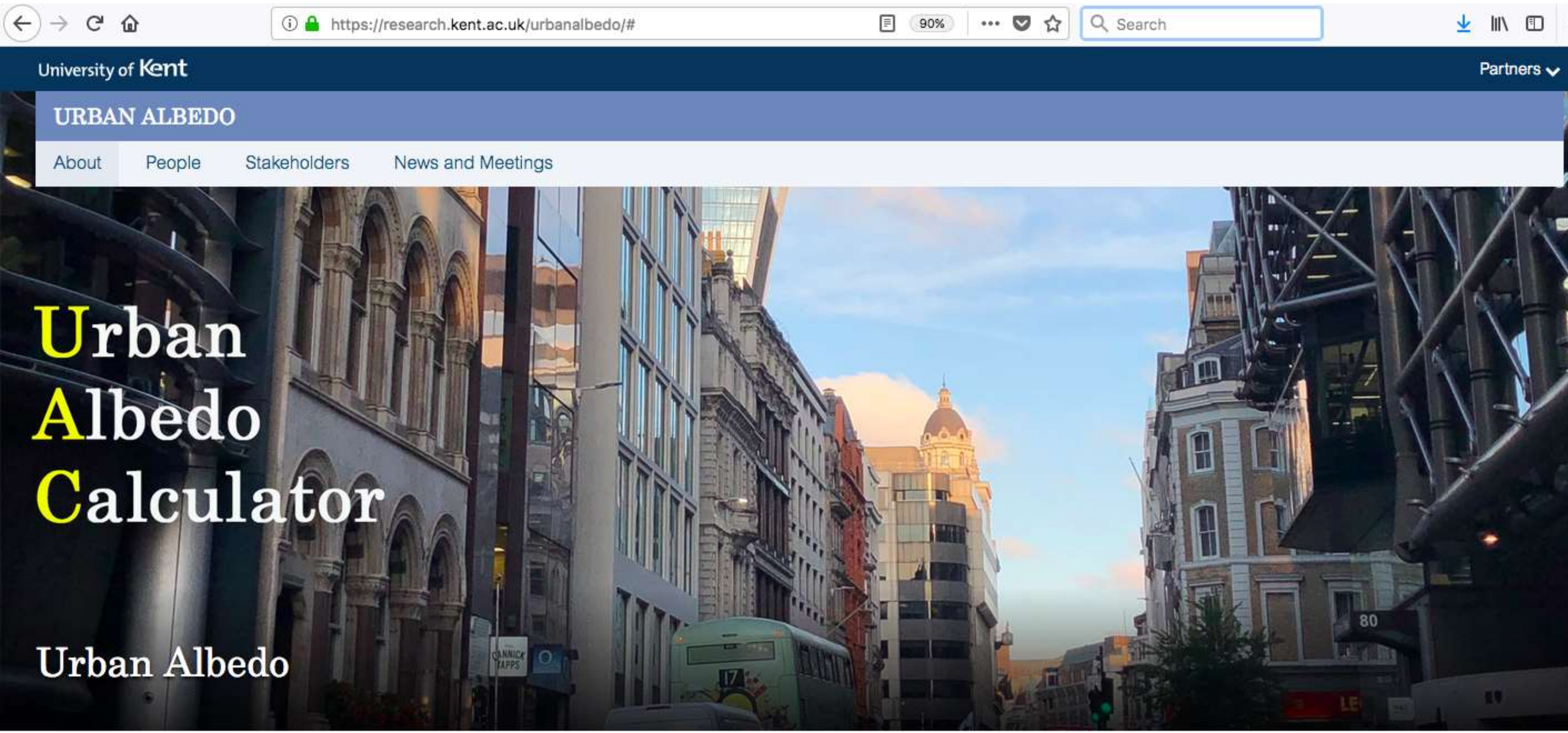

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EPSRC Engineering and Physical Sciences Research Council http://climatelondon.org/projects/urban-albedo/

Current projects

Previous projects

Projects categories

- Built Environment (3)
- Business (4)
- Drought (1)
- Flooding (1)
- Health & Wellbeing (6)
- Housing (2)
- Local Authorities (3)
- Natural Environment (1)
- Overheating (3)
- Smart Cities (1)
- Transport & Infrastructure (2)

Projects

Urban Albedo

Urban Albedo Computation in High-Latitude Locations: An Experimental Approach (Urban Albedo)

The Urban Albedo project is a partnership between Kent University, Loughborough University, and Brunel University, funded by EPSRC.

The project aims and objectives are to:

- Incorporate accurate calculation and prediction of urban albedo in the planning and design process
- Investigate experimentally the impact of urban fabric on urban albedo, using London as a case study
- Develop a catalogue of urban albedo for various materials and geometrical confugurations
- Develop an urban albedo calculator, an empirical model to predict changes in urban albedo in relation to changes in urban fabric and solar altitude

Find an introductory presentation about the project here.

Read the Urban Albedo Fact Sheet here.

Public events

Eventbrite

Search for events

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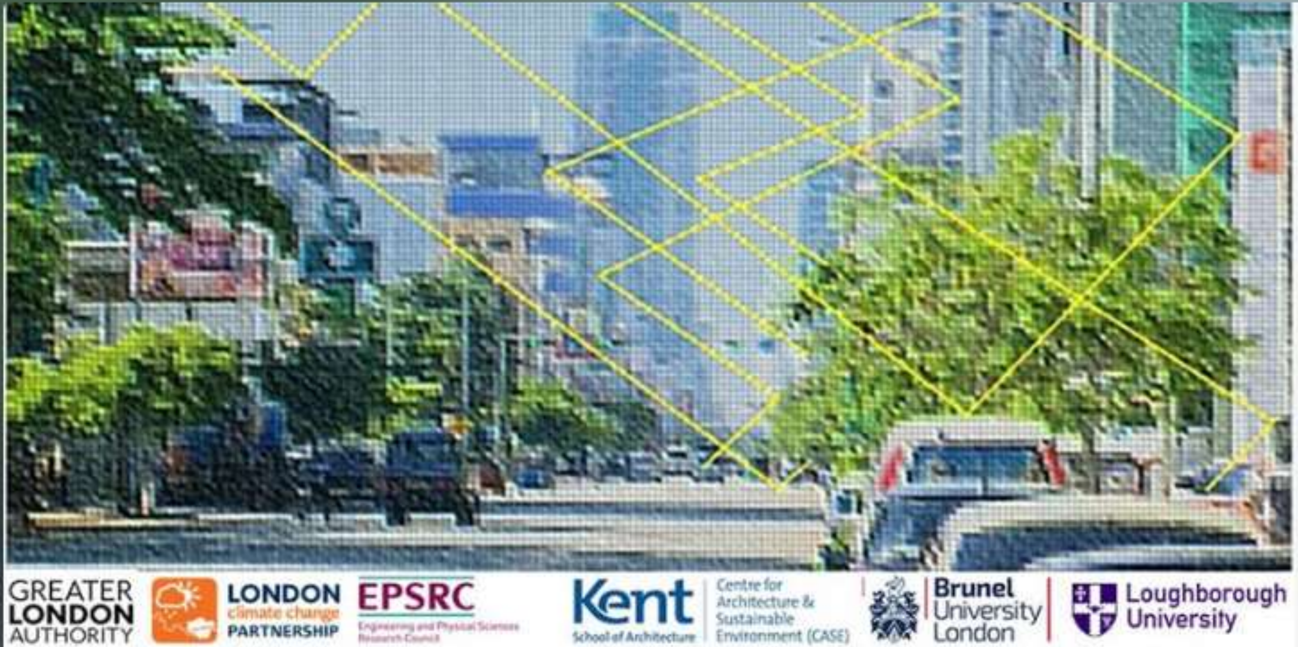

OCT
15

Urban Albedo: Digital tools for urban resilience and growth

by GLA, LCCP, University of Kent, Brunel University London, Loughborough Unive...

Free

REGISTER

DESCRIPTION

Urban albedo -capacity of urban surfaces to reflect solar radiation- is one of the most important contributors to changes in outdoor temperature, intensifying the urban heat island phenomenon. The Greater London Authority has identified urban albedo as one of the most significant parameters for mitigating the Urban Heat Island in London. The 'Urban Albedo Calculator' EPSRC-funded project along

DATE AND TIME

Mon 15 October 2018
10:30 – 16:00 BST
Add to Calendar

LOCATION

Urban Albedo

Digital Tools for Urban Resilience and Growth

Thank you!

Monday 15th October, London Living Room, Green GB week

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EPSRC Engineering and Physical Sciences Research Council

Greater London Authority

London climate change partnership