

Urban Albedo Computation in high latitude locations: an experimental approach



Heat Risk in London Group
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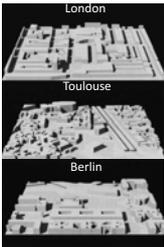
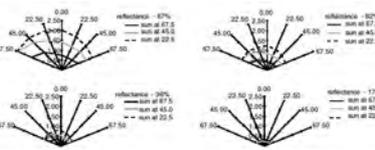


Project aims & objectives

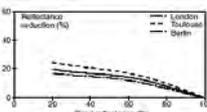
- Incorporate *accurate* calculation and prediction of urban albedo in the planning and design process
- Investigate experimentally the impact of **urban fabric** on urban albedo, using on London as a case-study
- Develop a **catalogue** of urban albedo for various **materials** and **geometrical** configurations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



Radiation absorption and urban texture

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

Steemers, Baker, Crowther, Nikolopoulou, Dubiel (1998) "Radiation absorption and urban texture", *Building Research and Information*, Vol. 26.



Advisory Group



- Greater London Authority (GLA)
- Ibstock Brick Limited
- SWECO UK Limited
- CIBSE - Resilient Cities Special Interest Group
- Adaptation and Resilience in the Context of Change network
- London Climate Change Programme (LCCP)
- European Cool Roof Council (ECRC)
- Michael Bruse: ENVI-MET
- Leading Academics
 - ✓ Sue Grimmond, Reading
 - ✓ Anna Mavrogianni, UCL



Project tasks

- Task 1: Urban survey and 3D scanning
- Task 2: Experimental model
- Task 3: Weathering
- Task 4: Urban albedo calculator
- Task 5: Urban modelling and simulation
- Task 6: Dissemination and outreach



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 2002¹
- 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 Areas²
 - ✓ Areas with higher average surface temperature profile³, as modelled with LondUM⁴ for the period 26 May 2006 - 31 Aug 2006.

¹Richard 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/development/london-plan/opportunity-areas/opportunity-areas>
³<https://data.london.gov.uk/dataset/london-s-urban-heat-island>
⁴Jonathan 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 & Oke¹
- New sub-zones will be developed for cases that are not represented in the existing LCZs

Classification code (LCZ)	Typical height (m)	Aspect ratio	Building footprint	Vegetation cover (%)	Percentage of impervious surface (%)	Height of impervious surface (m)	Typical surface material
LCZ 1	0.5-1.0	1.0	0.2-0.3	0-10	10-20	1-2	Asphalt
LCZ 2	1.0-2.0	1.0	0.3-0.4	0-10	20-30	2-3	Asphalt
LCZ 3	2.0-3.0	1.0	0.4-0.5	0-10	30-40	3-4	Asphalt
LCZ 4	3.0-4.0	1.0	0.5-0.6	0-10	40-50	4-5	Asphalt
LCZ 5	4.0-6.0	1.0	0.6-0.7	0-10	50-60	5-6	Asphalt
LCZ 6	6.0-9.0	1.0	0.7-0.8	0-10	60-70	6-7	Asphalt
LCZ 7	9.0-13.0	1.0	0.8-0.9	0-10	70-80	7-8	Asphalt
LCZ 8	13.0-18.0	1.0	0.9-1.0	0-10	80-90	8-9	Asphalt
LCZ 9	18.0-30.0	1.0	1.0-1.1	0-10	90-100	9-10	Asphalt
LCZ 10	30.0-60.0	1.0	1.1-1.2	0-10	100	10-12	Asphalt
LCZ 11	60.0-90.0	1.0	1.2-1.3	0-10	100	12-15	Asphalt
LCZ 12	90.0-150.0	1.0	1.3-1.4	0-10	100	15-20	Asphalt
LCZ 13	150.0-250.0	1.0	1.4-1.5	0-10	100	20-25	Asphalt
LCZ 14	250.0-500.0	1.0	1.5-1.6	0-10	100	25-30	Asphalt
LCZ 15	500.0-1000.0	1.0	1.6-1.7	0-10	100	30-35	Asphalt
LCZ 16	1000.0-2000.0	1.0	1.7-1.8	0-10	100	35-40	Asphalt
LCZ 17	2000.0-3000.0	1.0	1.8-1.9	0-10	100	40-45	Asphalt
LCZ 18	3000.0-5000.0	1.0	1.9-2.0	0-10	100	45-50	Asphalt
LCZ 19	5000.0-10000.0	1.0	2.0-2.1	0-10	100	50-55	Asphalt
LCZ 20	10000.0-20000.0	1.0	2.1-2.2	0-10	100	55-60	Asphalt
LCZ 21	20000.0-50000.0	1.0	2.2-2.3	0-10	100	60-65	Asphalt
LCZ 22	50000.0-100000.0	1.0	2.3-2.4	0-10	100	65-70	Asphalt
LCZ 23	100000.0-200000.0	1.0	2.4-2.5	0-10	100	70-75	Asphalt
LCZ 24	200000.0-500000.0	1.0	2.5-2.6	0-10	100	75-80	Asphalt
LCZ 25	500000.0-1000000.0	1.0	2.6-2.7	0-10	100	80-85	Asphalt
LCZ 26	1000000.0-2000000.0	1.0	2.7-2.8	0-10	100	85-90	Asphalt
LCZ 27	2000000.0-5000000.0	1.0	2.8-2.9	0-10	100	90-95	Asphalt
LCZ 28	5000000.0-10000000.0	1.0	2.9-3.0	0-10	100	95-100	Asphalt
LCZ 29	10000000.0-20000000.0	1.0	3.0-3.1	0-10	100	100	Asphalt
LCZ 30	20000000.0-50000000.0	1.0	3.1-3.2	0-10	100	100	Asphalt
LCZ 31	50000000.0-100000000.0	1.0	3.2-3.3	0-10	100	100	Asphalt
LCZ 32	100000000.0-200000000.0	1.0	3.3-3.4	0-10	100	100	Asphalt
LCZ 33	200000000.0-500000000.0	1.0	3.4-3.5	0-10	100	100	Asphalt
LCZ 34	500000000.0-1000000000.0	1.0	3.5-3.6	0-10	100	100	Asphalt
LCZ 35	1000000000.0-2000000000.0	1.0	3.6-3.7	0-10	100	100	Asphalt
LCZ 36	2000000000.0-5000000000.0	1.0	3.7-3.8	0-10	100	100	Asphalt
LCZ 37	5000000000.0-10000000000.0	1.0	3.8-3.9	0-10	100	100	Asphalt
LCZ 38	10000000000.0-20000000000.0	1.0	3.9-4.0	0-10	100	100	Asphalt
LCZ 39	20000000000.0-50000000000.0	1.0	4.0-4.1	0-10	100	100	Asphalt
LCZ 40	50000000000.0-100000000000.0	1.0	4.1-4.2	0-10	100	100	Asphalt
LCZ 41	100000000000.0-200000000000.0	1.0	4.2-4.3	0-10	100	100	Asphalt
LCZ 42	200000000000.0-500000000000.0	1.0	4.3-4.4	0-10	100	100	Asphalt
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LCZ 53	1000000000000000.0-2000000000000000.0	1.0	5.4-5.5	0-10	100	100	Asphalt
LCZ 54	2000000000000000.0-5000000000000000.0	1.0	5.5-5.6	0-10	100	100	Asphalt
LCZ 55	5000000000000000.0-10000000000000000.0	1.0	5.6-5.7	0-10	100	100	Asphalt
LCZ 56	10000000000000000.0-20000000000000000.0	1.0	5.7-5.8	0-10	100	100	Asphalt
LCZ 57	20000000000000000.0-50000000000000000.0	1.0	5.8-5.9	0-10	100	100	Asphalt
LCZ 58	50000000000000000.0-100000000000000000.0	1.0	5.9-6.0	0-10	100	100	Asphalt
LCZ 59	100000000000000000.0-200000000000000000.0	1.0	6.0-6.1	0-10	100	100	Asphalt
LCZ 60	200000000000000000.0-500000000000000000.0	1.0	6.1-6.2	0-10	100	100	Asphalt
LCZ 61	500000000000000000.0-1000000000000000000.0	1.0	6.2-6.3	0-10	100	100	Asphalt
LCZ 62	1000000000000000000.0-2000000000000000000.0	1.0	6.3-6.4	0-10	100	100	Asphalt
LCZ 63	2000000000000000000.0-5000000000000000000.0	1.0	6.4-6.5	0-10	100	100	Asphalt
LCZ 64	5000000000000000000.0-10000000000000000000.0	1.0	6.5-6.6	0-10	100	100	Asphalt
LCZ 65	10000000000000000000.0-20000000000000000000.0	1.0	6.6-6.7	0-10	100	100	Asphalt
LCZ 66	20000000000000000000.0-50000000000000000000.0	1.0	6.7-6.8	0-10	100	100	Asphalt
LCZ 67	50000000000000000000.0-100000000000000000000.0	1.0	6.8-6.9	0-10	100	100	Asphalt
LCZ 68	100000000000000000000.0-200000000000000000000.0	1.0	6.9-7.0	0-10	100	100	Asphalt
LCZ 69	200000000000000000000.0-500000000000000000000.0	1.0	7.0-7.1	0-10	100	100	Asphalt
LCZ 70	500000000000000000000.0-1000000000000000000000.0	1.0	7.1-7.2	0-10	100	100	Asphalt
LCZ 71	1000000000000000000000.0-2000000000000000000000.0	1.0	7.2-7.3	0-10	100	100	Asphalt
LCZ 72	2000000000000000000000.0-5000000000000000000000.0	1.0	7.3-7.4	0-10	100	100	Asphalt
LCZ 73	5000000000000000000000.0-10000000000000000000000.0	1.0	7.4-7.5	0-10	100	100	Asphalt
LCZ 74	10000000000000000000000.0-20000000000000000000000.0	1.0	7.5-7.6	0-10	100	100	Asphalt
LCZ 75	20000000000000000000000.0-50000000000000000000000.0	1.0	7.6-7.7	0-10	100	100	Asphalt
LCZ 76	50000000000000000000000.0-100000000000000000000000.0	1.0	7.7-7.8	0-10	100	100	Asphalt
LCZ 77	100000000000000000000000.0-200000000000000000000000.0	1.0	7.8-7.9	0-10	100	100	Asphalt
LCZ 78	200000000000000000000000.0-500000000000000000000000.0	1.0	7.9-8.0	0-10	100	100	Asphalt
LCZ 79	500000000000000000000000.0-1000000000000000000000000.0	1.0	8.0-8.1	0-10	100	100	Asphalt
LCZ 80	1000000000000000000000000.0-2000000000000000000000000.0	1.0	8.1-8.2	0-10	100	100	Asphalt
LCZ 81	2000000000000000000000000.0-5000000000000000000000000.0	1.0	8.2-8.3	0-10	100	100	Asphalt
LCZ 82	5000000000000000000000000.0-10000000000000000000000000.0	1.0	8.3-8.4	0-10	100	100	Asphalt
LCZ 83	10000000000000000000000000.0-20000000000000000000000000.0	1.0	8.4-8.5	0-10	100	100	Asphalt
LCZ 84	20000000000000000000000000.0-50000000000000000000000000.0	1.0	8.5-8.6	0-10	100	100	Asphalt
LCZ 85	50000000000000000000000000.0-100000000000000000000000000.0	1.0	8.6-8.7	0-10	100	100	Asphalt
LCZ 86	100000000000000000000000000.0-200000000000000000000000000.0	1.0	8.7-8.8	0-10	100	100	Asphalt
LCZ 87	200000000000000000000000000.0-500000000000000000000000000.0	1.0	8.8-8.9	0-10	100	100	Asphalt
LCZ 88	500000000000000000000000000.0-1000000000000000000000000000.0	1.0	8.9-9.0	0-10	100	100	Asphalt
LCZ 89	1000000000000000000000000000.0-2000000000000000000000000000.0	1.0	9.0-9.1	0-10	100	100	Asphalt
LCZ 90	2000000000000000000000000000.0-5000000000000000000000000000.0	1.0	9.1-9.2	0-10	100	100	Asphalt
LCZ 91	5000000000000000000000000000.0-10000000000000000000000000000.0	1.0	9.2-9.3	0-10	100	100	Asphalt
LCZ 92	10000000000000000000000000000.0-20000000000000000000000000000.0	1.0	9.3-9.4	0-10	100	100	Asphalt
LCZ 93	20000000000000000000000000000.0-50000000000000000000000000000.0	1.0	9.4-9.5	0-10	100	100	Asphalt
LCZ 94	50000000000000000000000000000.0-100000000000000000000000000000.0	1.0	9.5-9.6	0-10	100	100	Asphalt
LCZ 95	100000000000000000000000000000.0-200000000000000000000000000000.0	1.0	9.6-9.7	0-10	100	100	Asphalt
LCZ 96	200000000000000000000000000000.0-500000000000000000000000000000.0	1.0	9.7-9.8	0-10	100	100	Asphalt
LCZ 97	500000000000000000000000000000.0-1000000000000000000000000000000.0	1.0	9.8-9.9	0-10	100	100	Asphalt
LCZ 98	1000000000000000000000000000000.0-2000000000000000000000000000000.0	1.0	9.9-10.0	0-10	100	100	

Experimental model – Inceptive concept

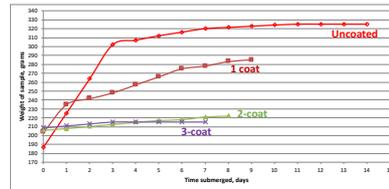
- The physical model will be built to 1:10 scale at the UKC campus using an area of 5m radius
- Use of plywood boxes to allow uncomplicated adjustment of model dimensions
- Materials to be attached onto the boxes.
- The initial concept for 300 x 300 x 300mm boxes, 11 mm thick, made in the University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



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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.



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.



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Experimental model – prototype



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Data acquisition

- Measurements to commence in July 2018.
- A pyranometer will be suspended 1m above the roof of the tallest block (i.e. 3m high equivalent to 10 storeys) at the centre of the model.
- Additional pyranometers will be placed above the roof (0.5m), above the ground (approx 0.25m) and on wall surfaces at critical positions to capture reflected radiation.
- Pyranometers will be connected to data loggers placed in a nearby monitoring room.
- Model will be equipped with probes to measure soil and air moisture at critical locations as well as surface temperature.
- A weather station close to the model will gather weather data during the measurement periods.
- Different equipment configurations have been explored.

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