Urban albedo and microclimate

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The project: Urban albedo computation in high latitude locations: An experimental approach

- Funded by EPSRC;
- Kent, Brunel and Loughborough Universities
- Website: https://research.kent.ac.uk/urbanalbedo/
- Industry partners: GLA, LCCP, ARCC, SWECO, CIBSE, Ibstock Brick Ltd, and ECRC.
- People:
- Kent: Marialena Nikolopoulou, Giridharan Renganathan , Richard Watkins, Alkis Kotopouleas , Muhammed Yeninarcilar
- Brunel: Maria Kolokotroni, Agnese Salvati
- Loughborough: Bala Vaidhyanathan, Aashu Anshuman

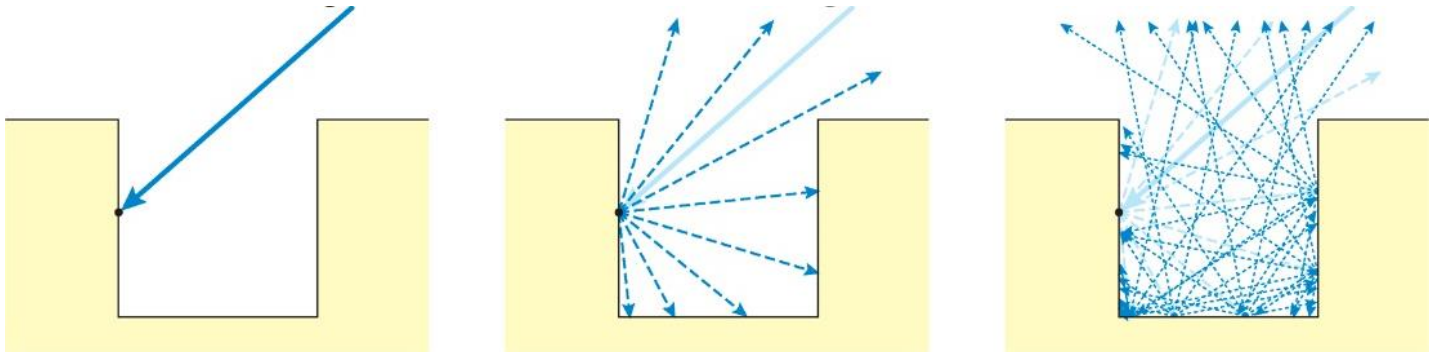
What is surface and urban albedo?

Surface albedo the total incoming shortwave radiation upon a surface. The higher the albedo, the higher the reflected radiation and the lower the surface temperature.

In an urban setting, the incoming radiation undergoes multiple reflections as it bounces between buildings.

Urban albedo is the weighted mean value of albedo in a cluster of buildings, depending on both materials and urban geometry.

Urban albedo is a major contributor to changes in outdoor surface and air temperature, intensifying the urban heat island which in turn impact on outside thermal comfort and energy demand by urban buildings.



Contributing factors to the value of urban albedo

- Geometry – the geometry of individual buildings, the building group geometry and the geometry of buildings in relation to roads, usually referred to as urban canyon geometry.
- Reflectance of surfaces and their orientation – ground, facades, roofs.

These two parameters are not related to latitude and climate, although climate impacts on urban development and materials used for buildings and there are indications that wetness of surfaces might affect reflectance.

- Sun altitude and azimuth determining the incidence angle of incoming solar radiation with strong seasonal contrasts in high latitudes.

Geometry, surface reflectance and sun's position are in many cases used to calculate the urban albedo.

- Moisture of permeable surfaces (soil) and by altering reflectivity of impermeable surfaces.
- Vegetation acting as obstruction to the incoming radiation and reflections paths.

These three parameters are closely related to climate. Moisture is connected to climatic conditions (air relative humidity) and precipitation. Similarly vegetation types differ according to prevailing climatic conditions and in many cases related to latitude (eg deciduous trees).

This presentation: investigation of the the impact of urban geometries and optical properties of facades and roads materials on UA and microclimate in a case-study residential location in London

A typical residential area was identified based on previous research (1)

Methods include:

- the construction of a 1:10 model of the urban area constructed at Kent University
- In-situ selective measurements in the actual case-study area,
- CFD modelling using EnviMet calibrated by the physical and scale model measurements,
- ray modelling using Radiance and
- laboratory characterization of the surface materials of the urban case-study.

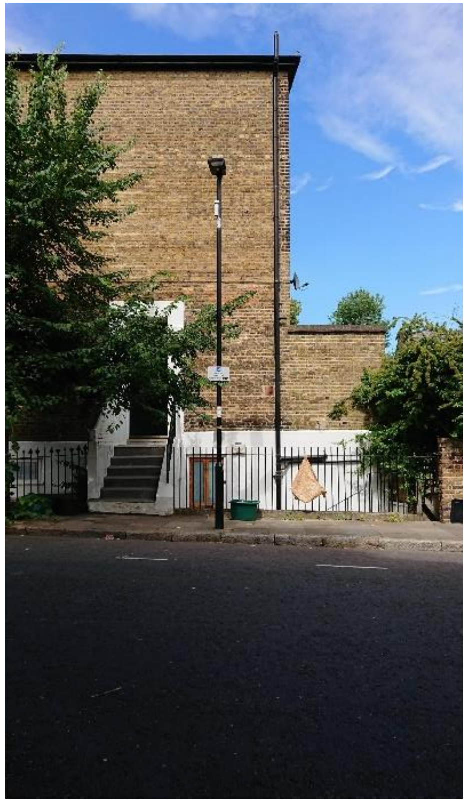
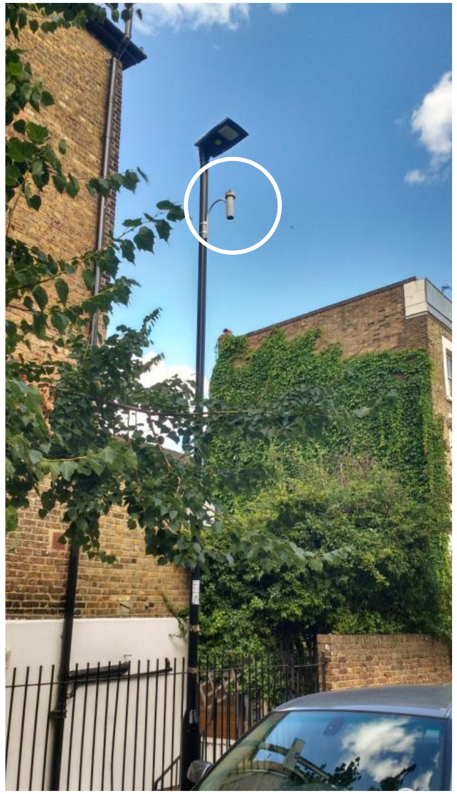
(1) Kolokotroni M and Giridharan R, (2008). *Urban Heat Island Intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during summer*, Solar Energy Vol 82, pp. 986-998

London case study area and 1:10 physical model

3D Scan

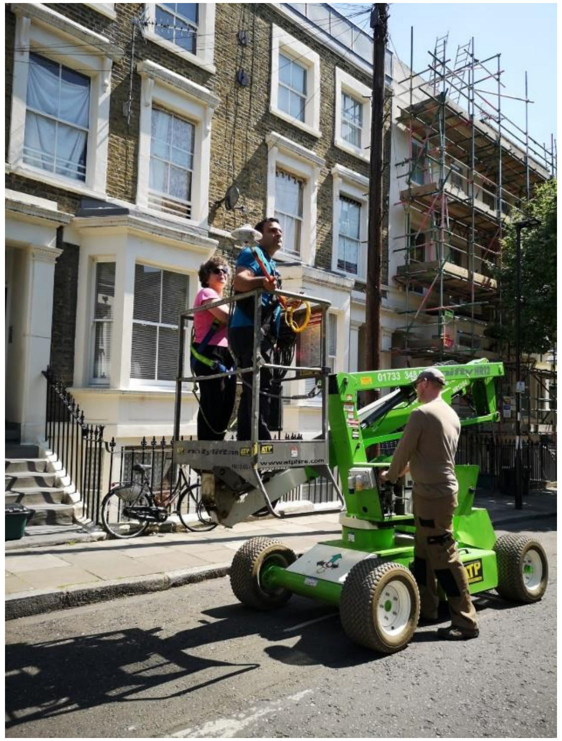
in-situ measurements

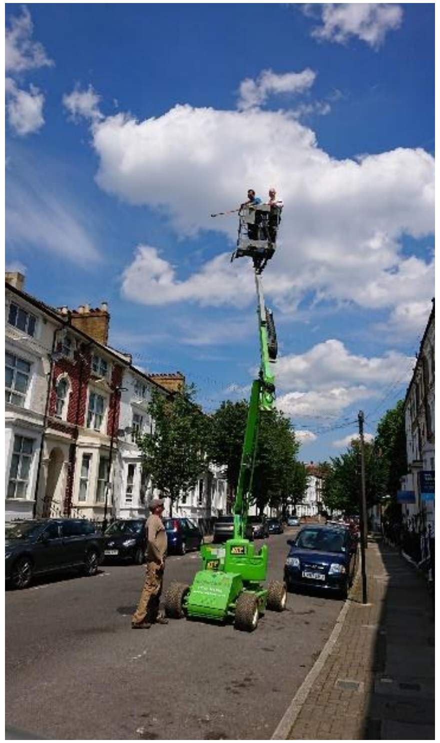
Air temperature monitoring with Bluetooth sensor installed at 5m height (average air temperature of the urban canyon)

in-situ measurements: Solar Radiation Measurements

Solar Radiation measurements at different heights
(incoming and outgoing radiation at different heights, from street level to eaves height)



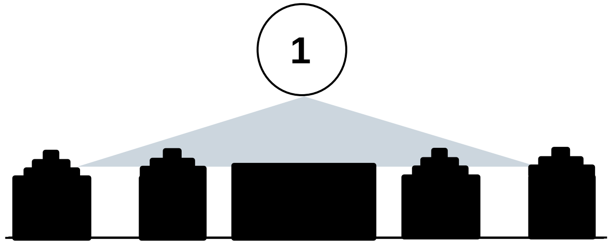


Physical model measurements at University of Kent

Up-facing Pyranometer

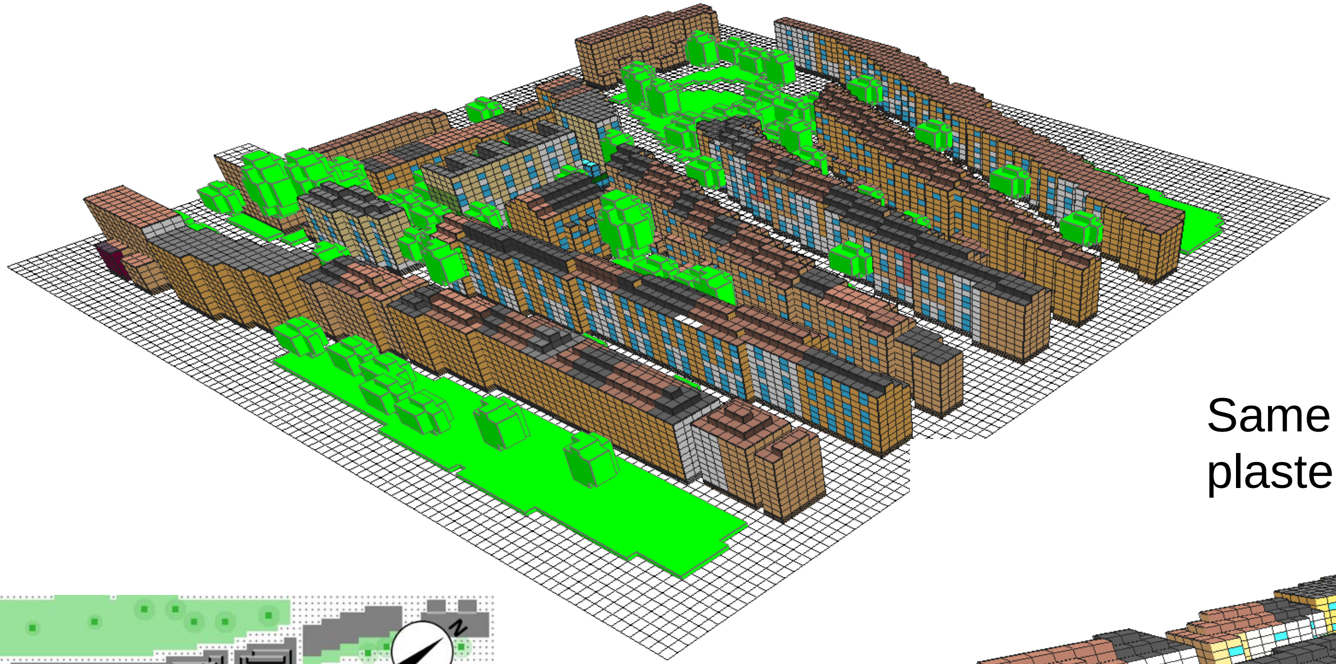
Down-facing pyranometer

Albedo on Top of model

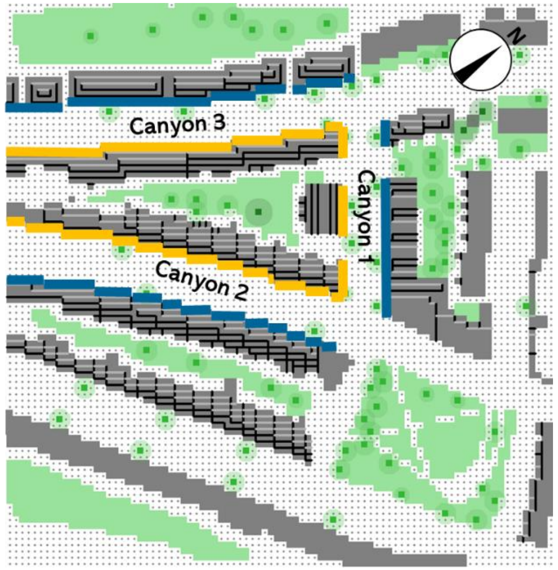


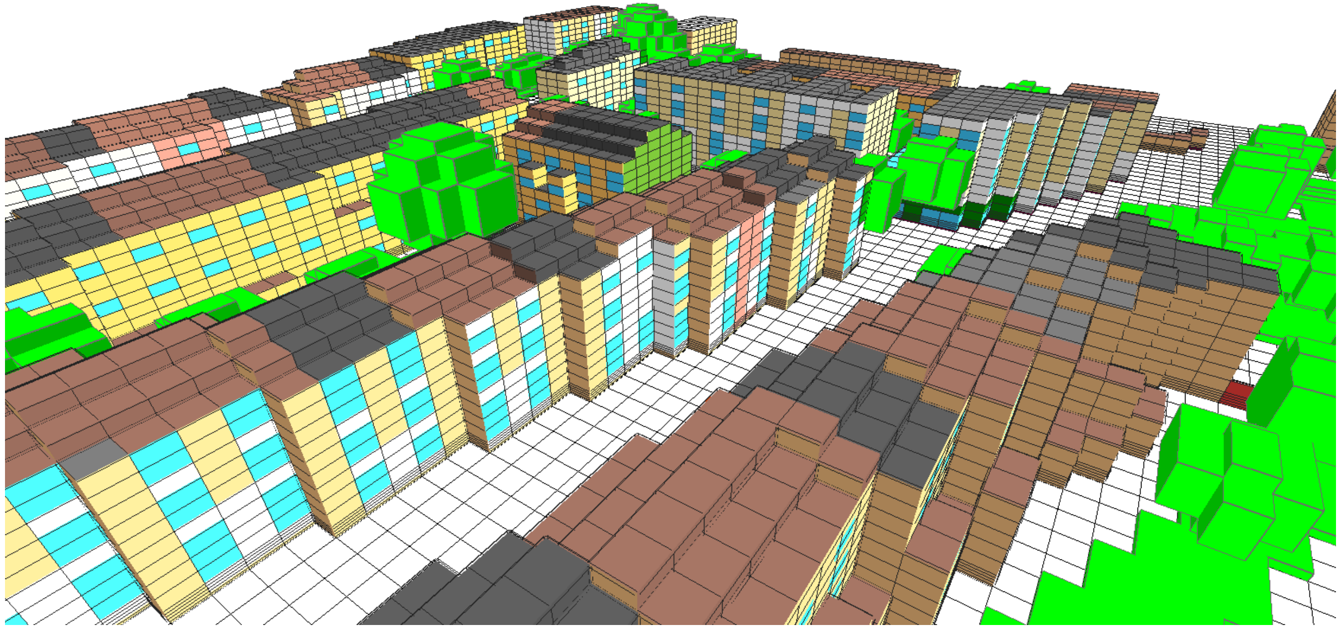
Urban canyon albedo

Microclimate model geometry and materials



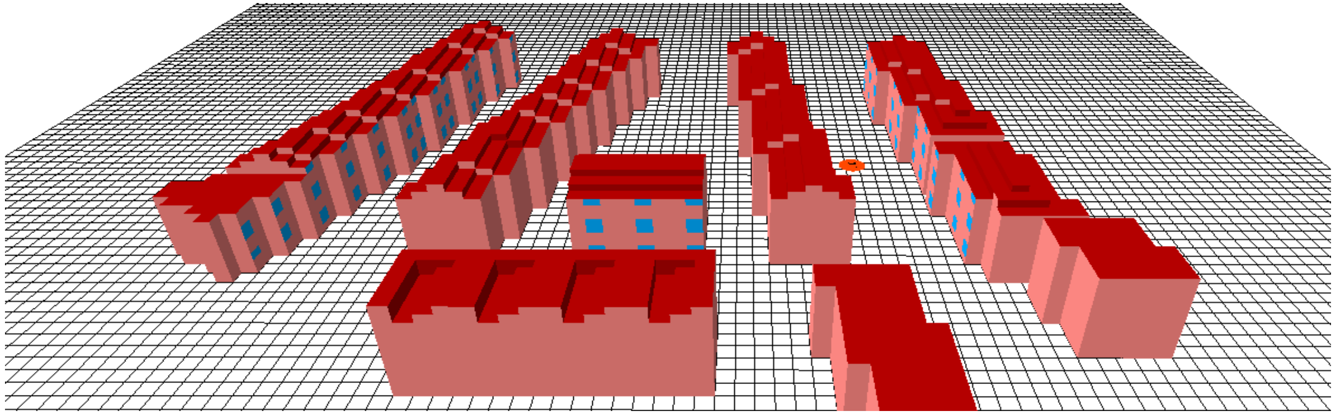
Same ratio of materials (i.e. bricks, glass, plaster) as the real case study





ENVImet models to evaluate the ENVImet IVS algorithm

1) **ENVImet model for the evaluation of the IVS algorithm for radiation transfer**



ENVImet simulation setup:

- Geometry and Materials' albedo as in the physical model
- Forcing radiation measured on the up-facing pyranometer (1)
- **IVS algorithm** (last release) for reflections

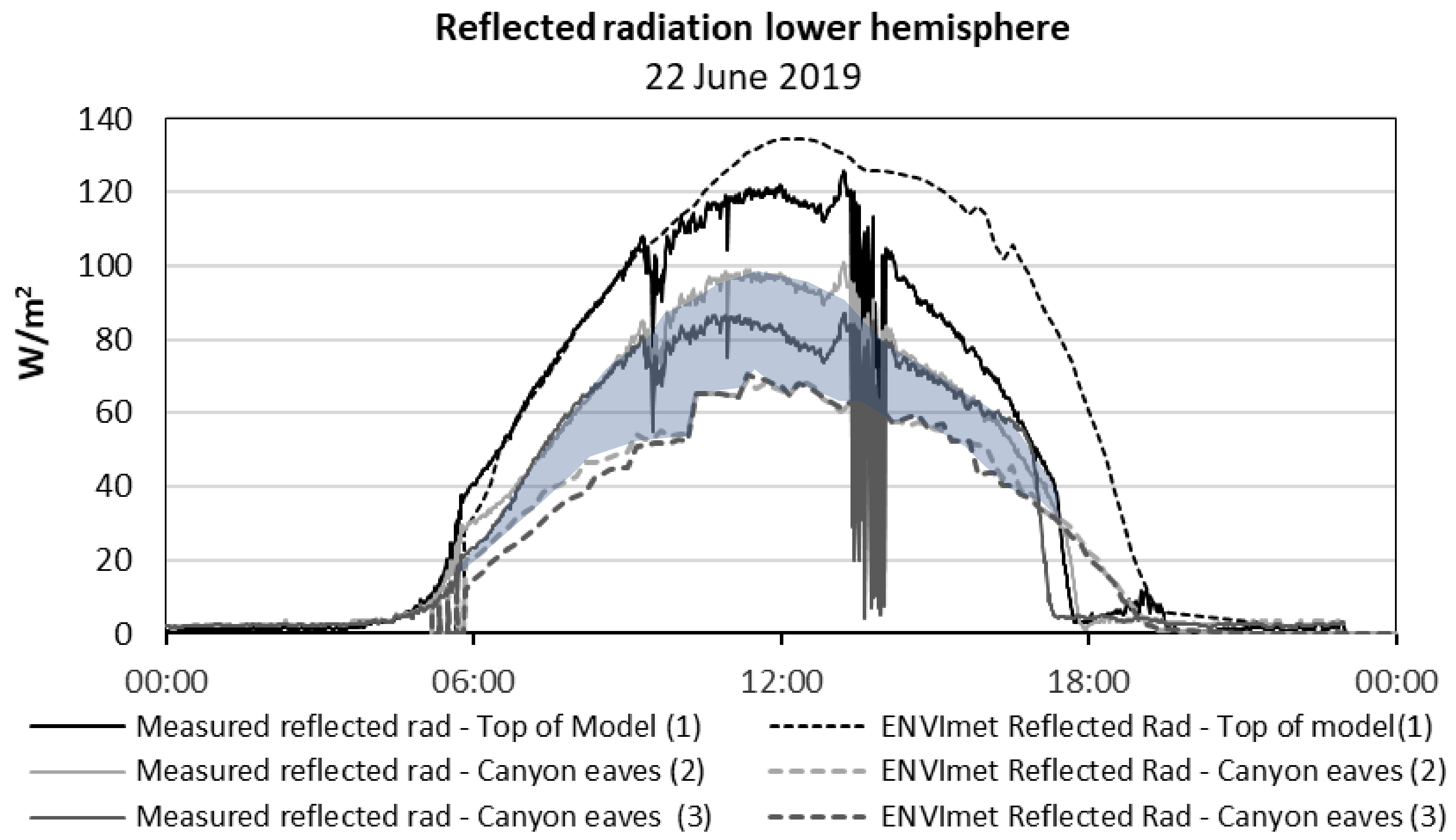
Simulation

ENVImet Radiation outputs :
Reflected radiation from the lower hemisphere

Compared to

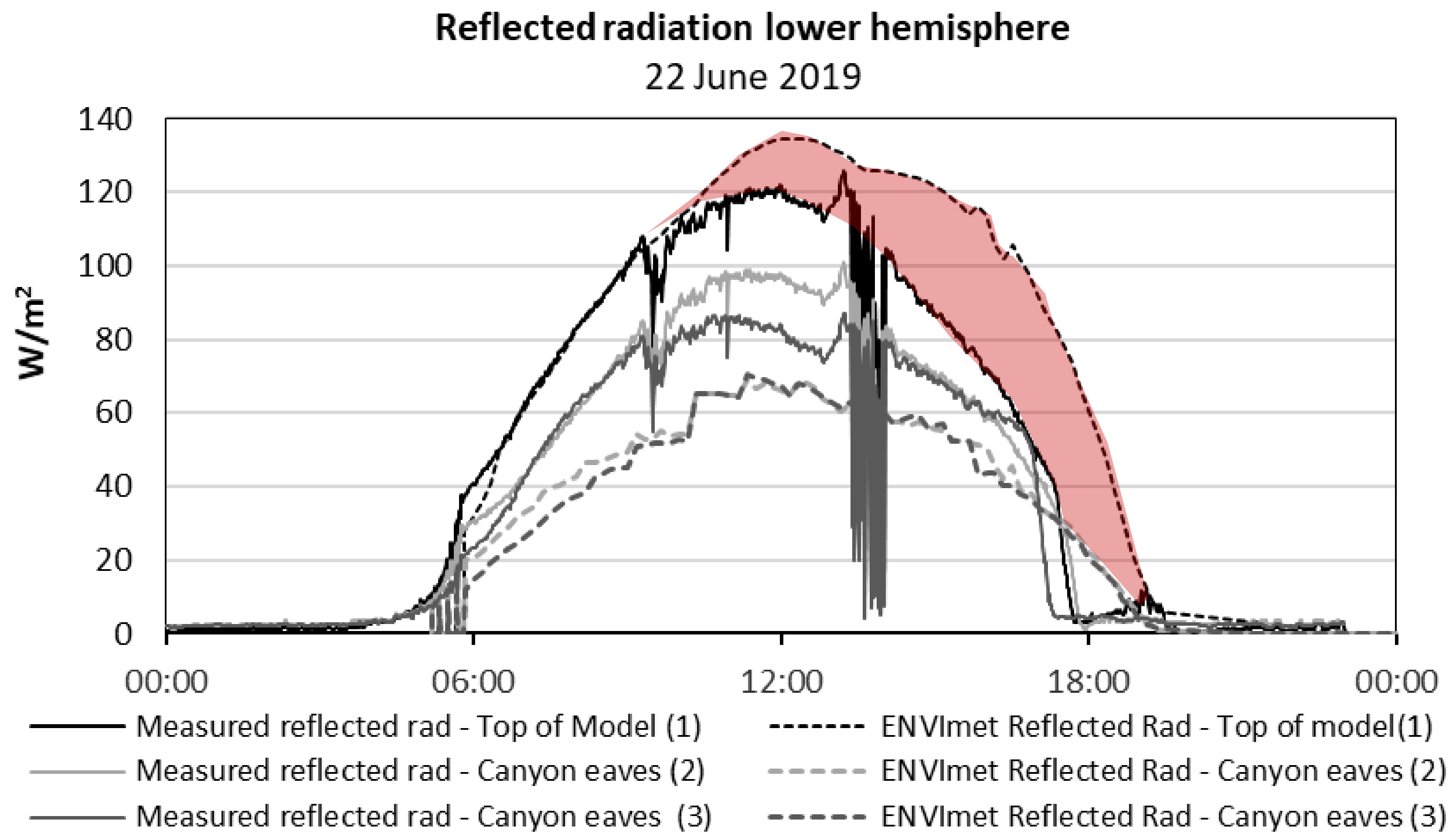
Measured reflected radiation on the physical model (down-facing pyranometers)

Accuracy of ENVImet reflections computation



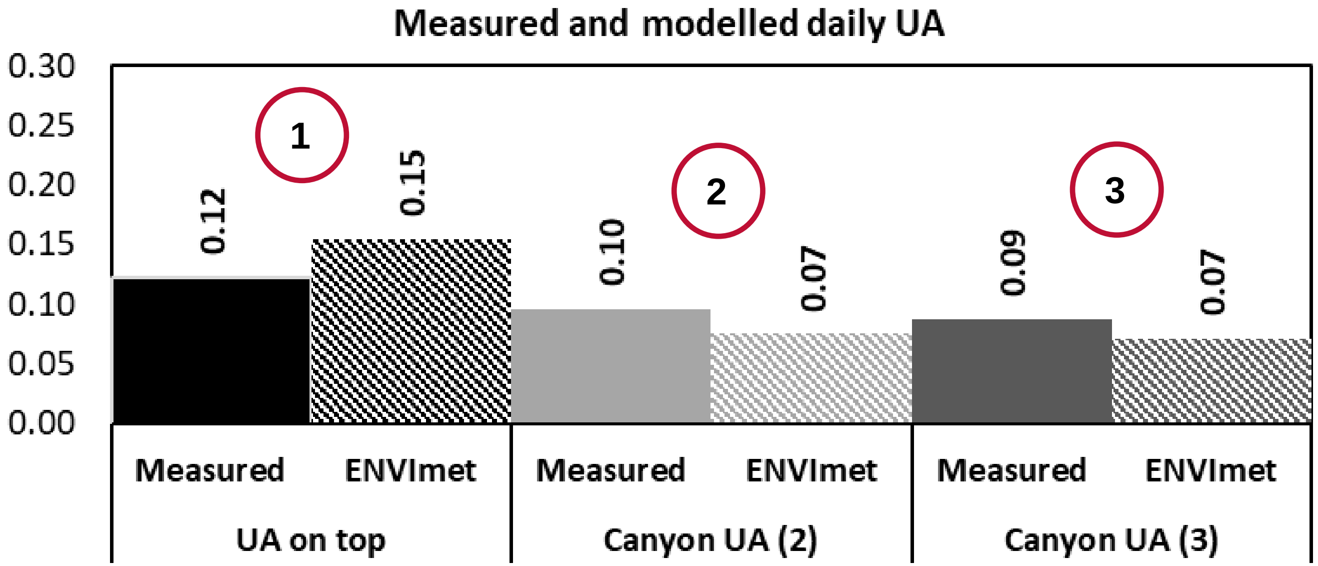
ENVImet slightly underestimates the reflections of solar radiation at the eaves level of urban canyons

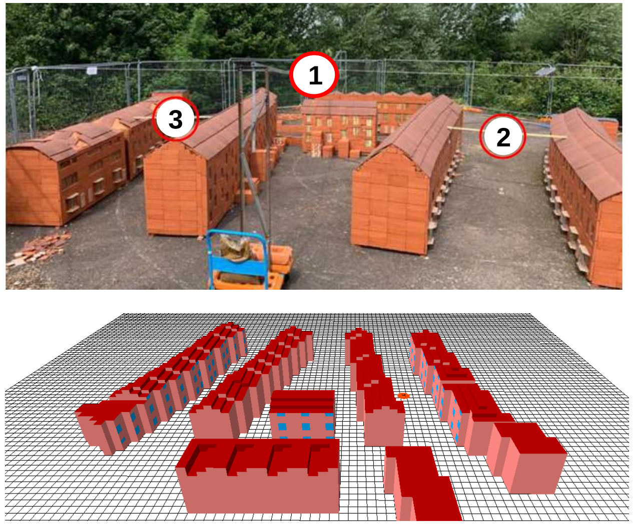
Accuracy of ENVImet reflections computation



ENVImet overestimates the reflections on top of the model from noon and until sunset

Accuracy of ENVImet reflections computation

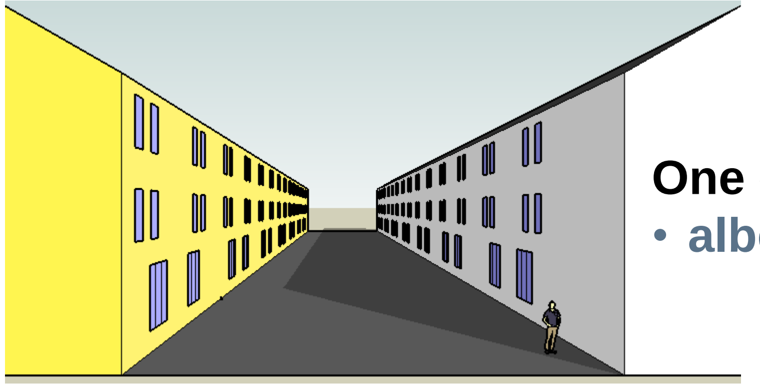




The daily Urban Albedo calculated by ENVImet is in good agreement with the measurements

Impact of reflective materials and geometry on UA: tested scenarios

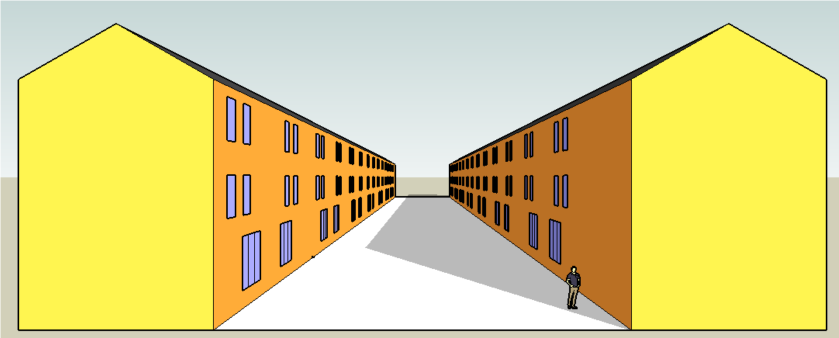
REFLECTIVE MATERIALS ON FACADES:



One of the two facades
- albedo 0.6

Top-half of both facades
- albedo 0.6

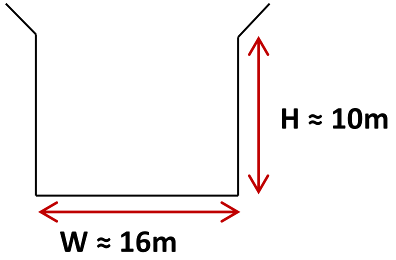
REFLECTIVE MATERIALS ON ROADS



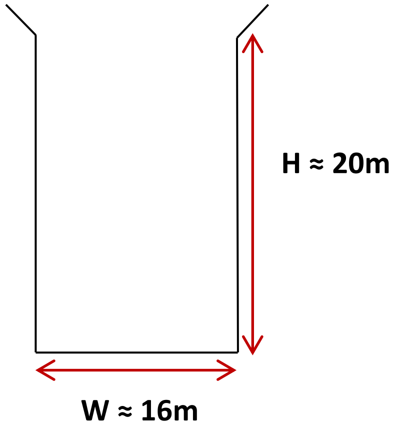
Road
- albedo 0.5

DIFFERENT URBAN GEOMETRIES:

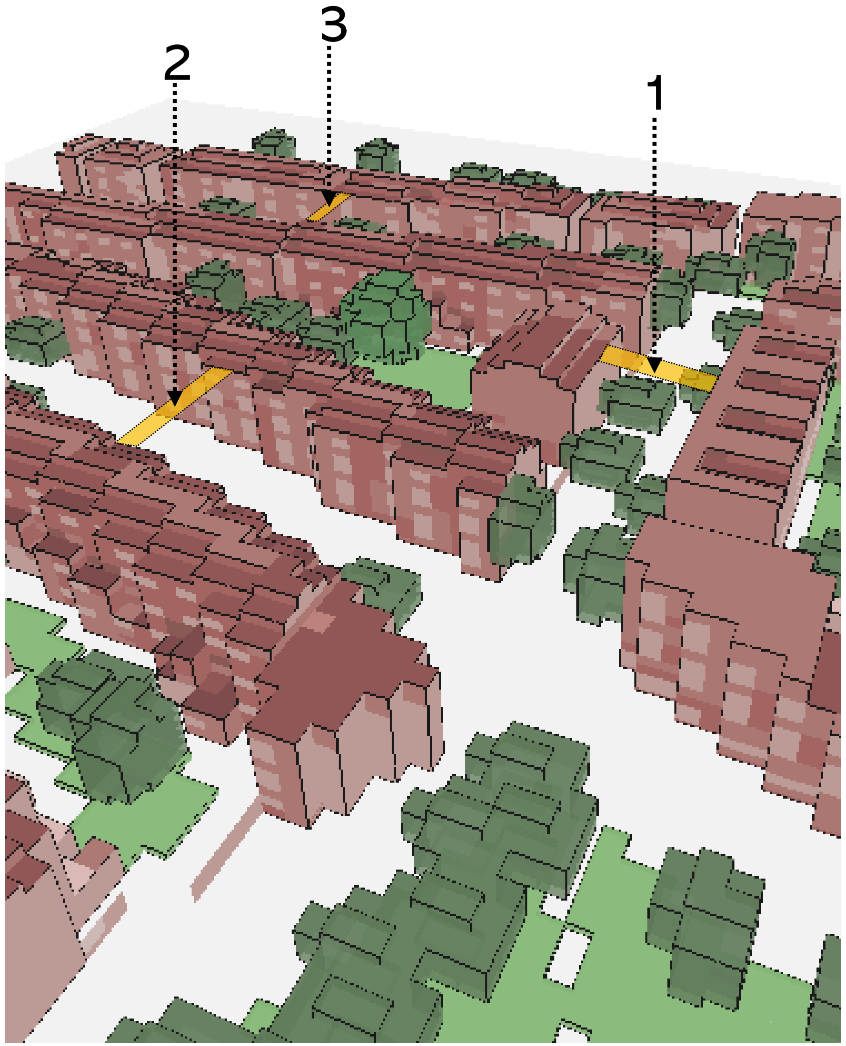
Canyon H/W ≈ 0.75

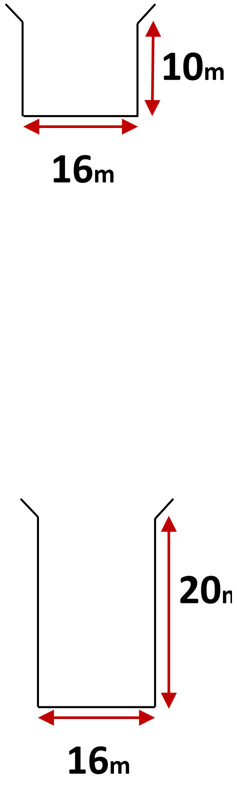


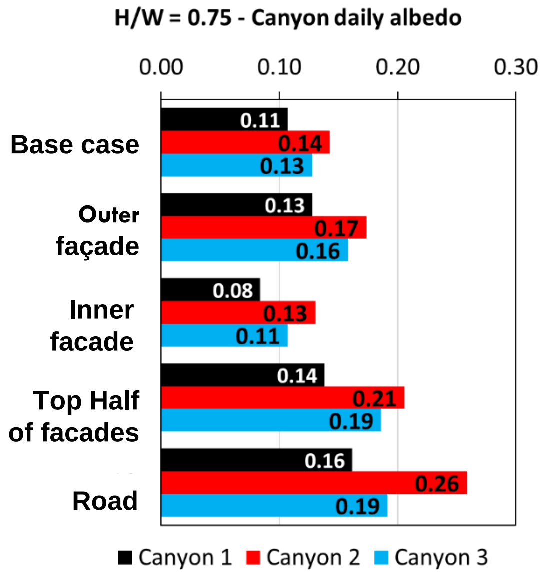
Canyon H/W ≈ 1.5

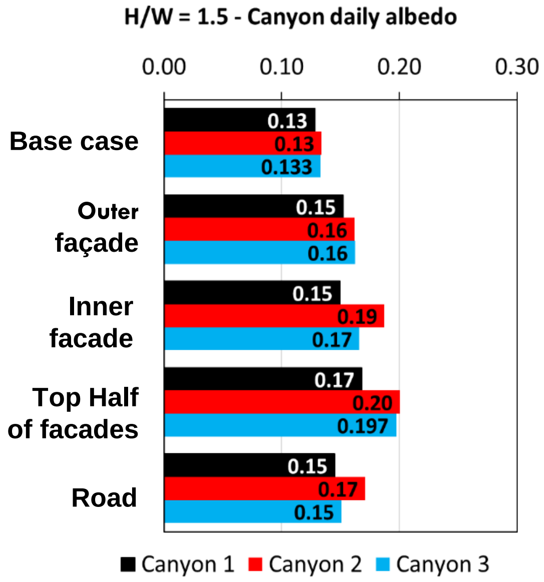


Impact of reflective materials and geometry on UA: tested scenarios







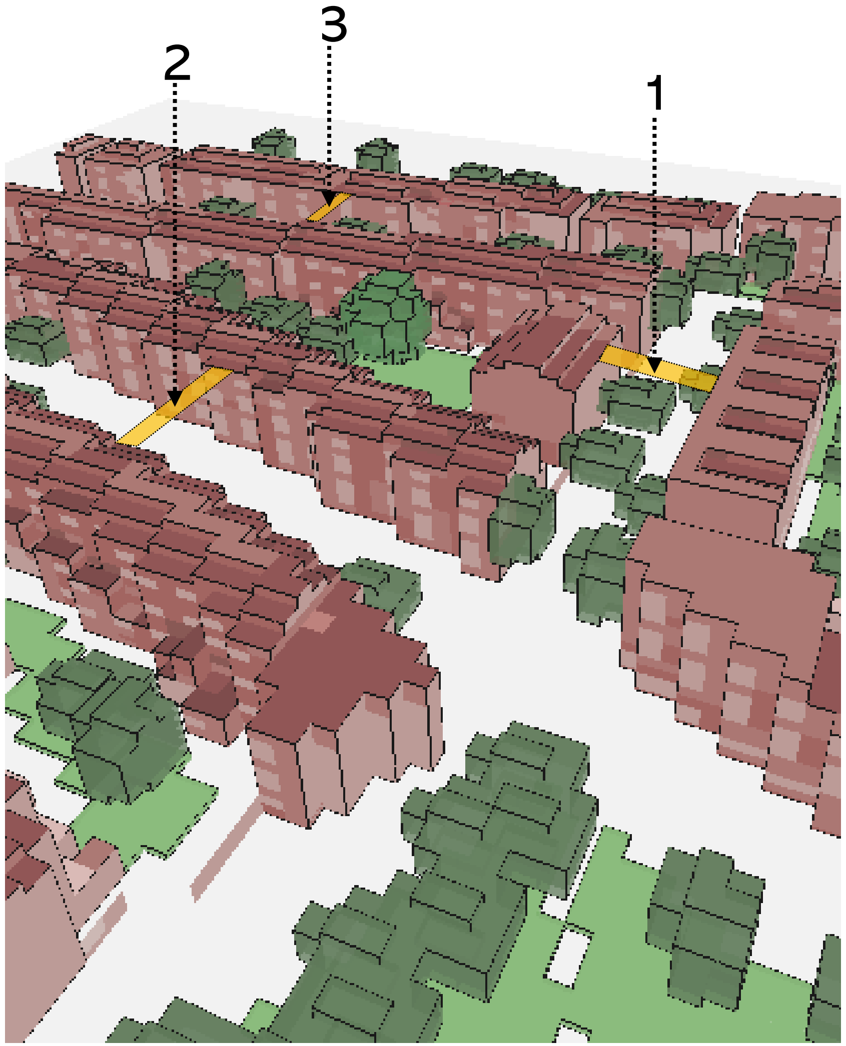


Reflective materials have a **larger impact in low-rise canyons**

The **highest increase of UA** is achieved by:

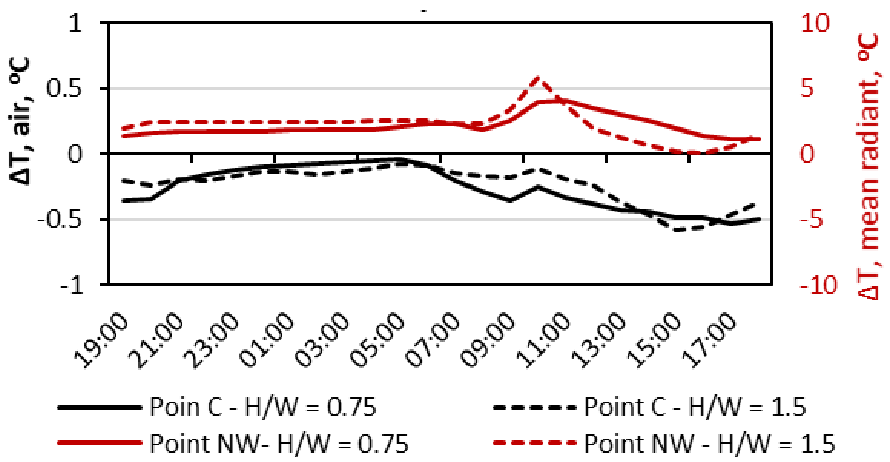
- **increasing the road reflectivity in the low-rise canyons**
- increasing the **reflectivity of the top-half part of the facades in high-rise canyons**

Impact of reflective materials on the street level microclimate



Impact on Air temperature and Mean radiant temperature

Increased **roads**' reflectivity
(canyon 2)

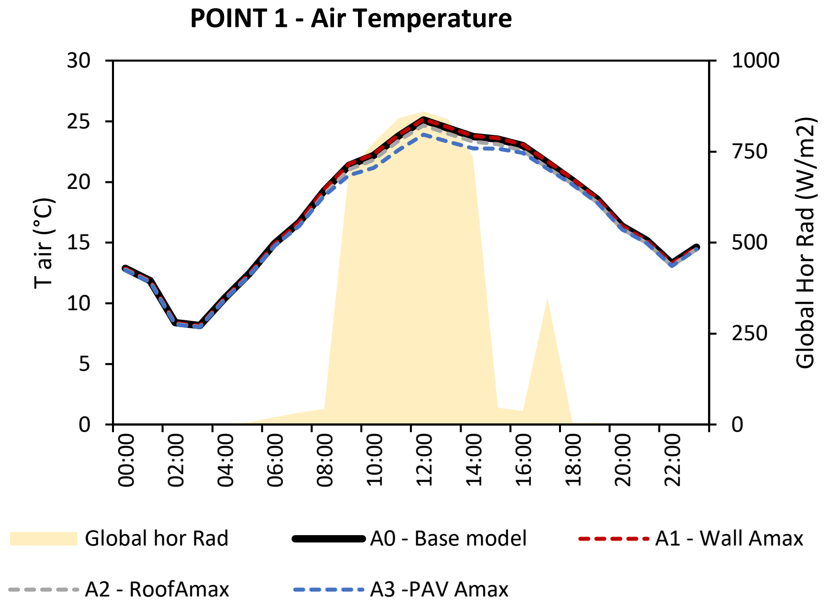


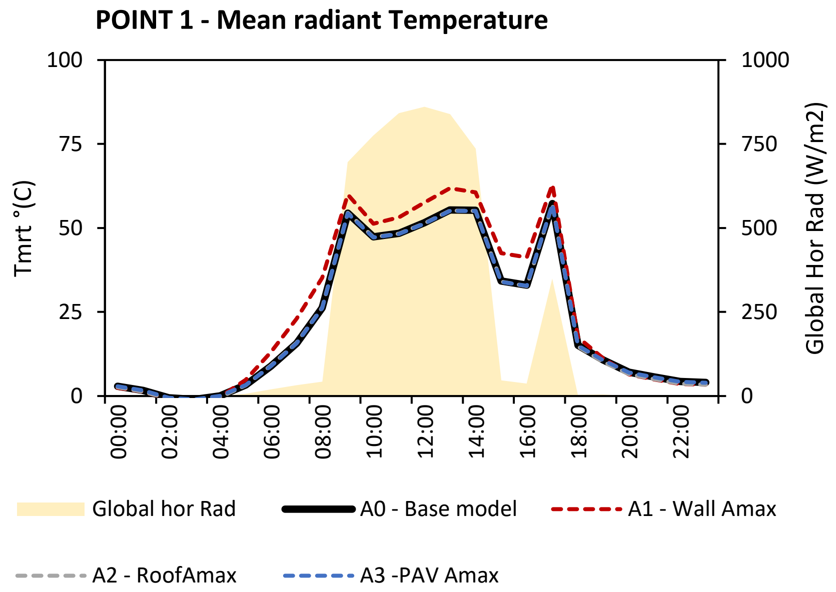
↑ Mean radiant temperature

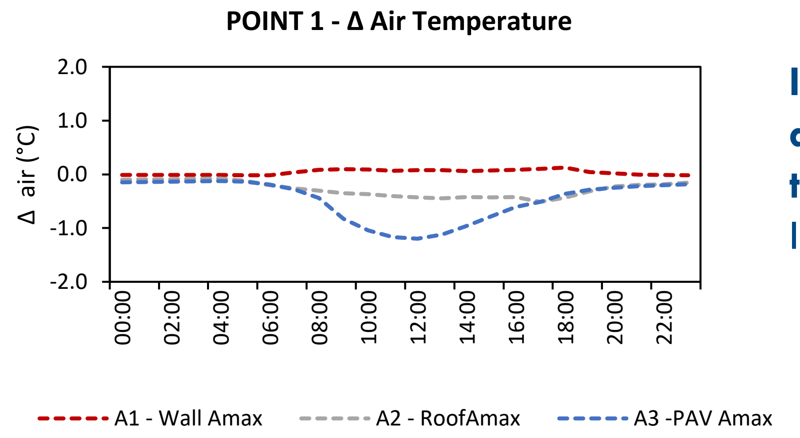
↓ Air temperature

Impact of high-reflectance materials on the street level microclimate

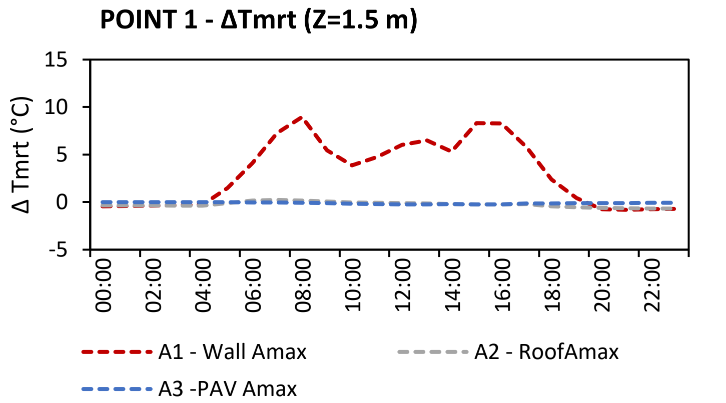
Street level (1.5 m) - Air temperature







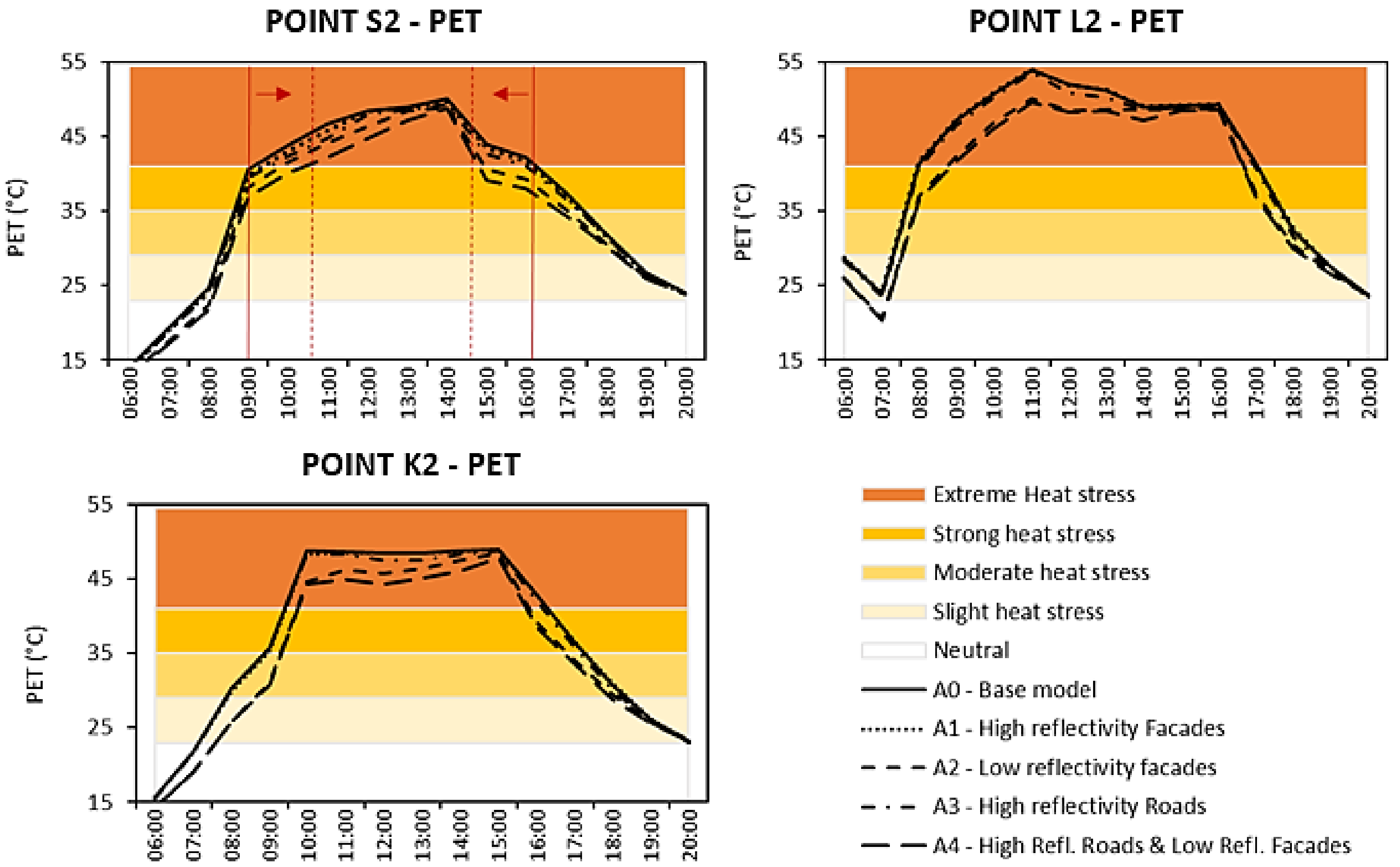
Increasing the roads albedo decreases air temperature at street level



Increasing the walls' albedo increases the mean radiant temperature at street level

Impact of urban albedo changes on microclimate and outdoor thermal comfort

Heatwave event | DETAILED ENVImet model | Measured air temperature data to force the simulation (29th of June 2019)



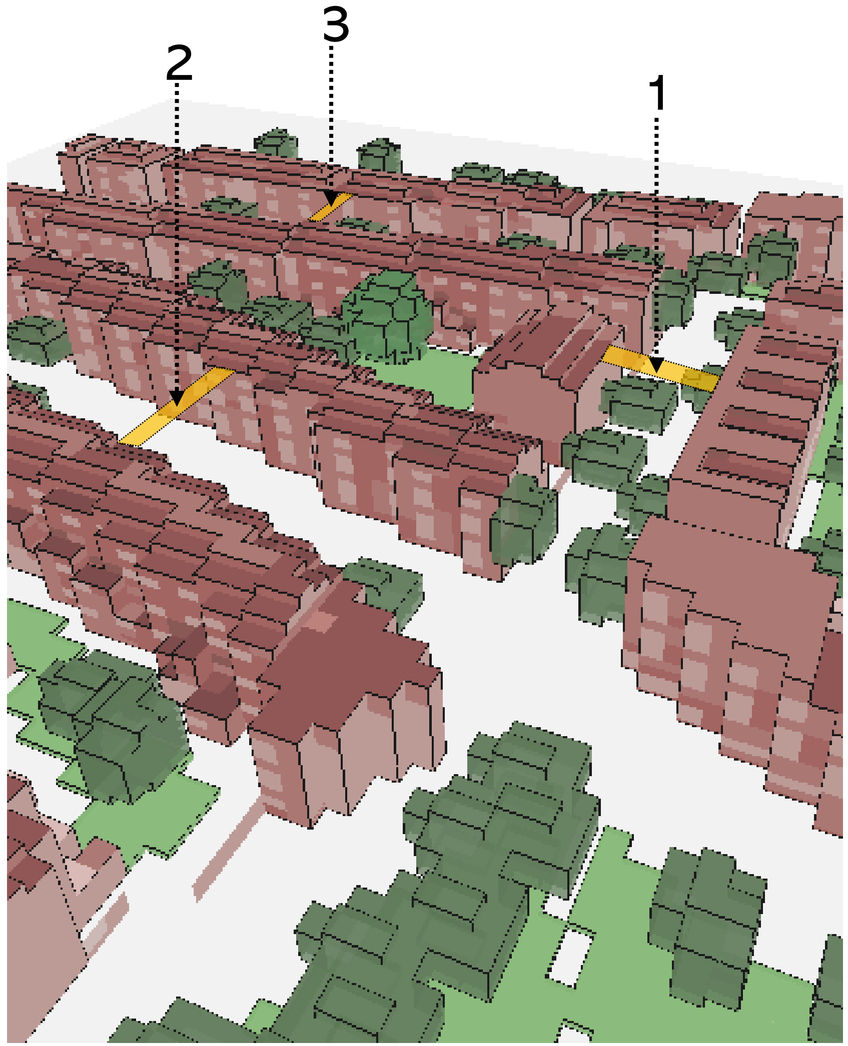
The scenario that allows to reduce the duration of "extreme het stress" over a heat wave event is the one with:

- **Increased reflectivity of roads**
- **Reduced reflectivity of walls**

This is due to the combined effect of a reduction of mean radiant temperatures and air temperature at street level.

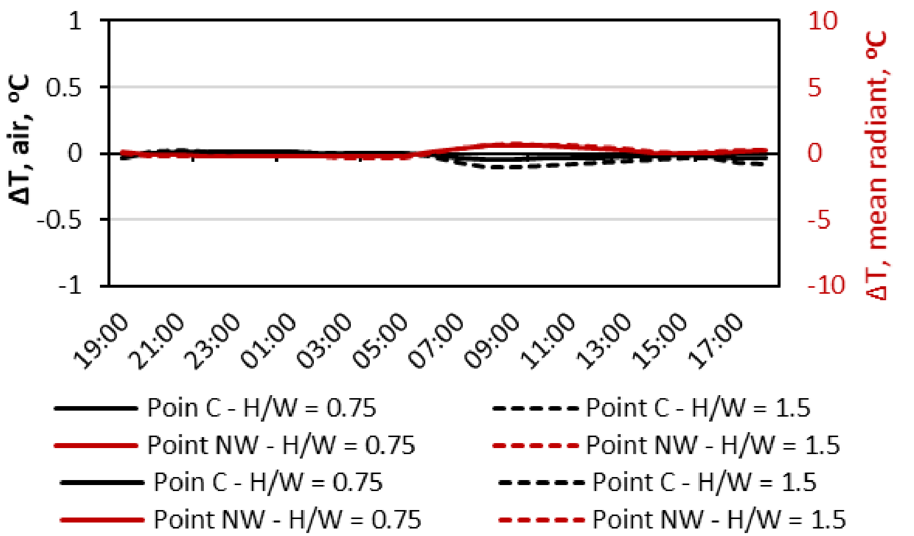
In this case, reducing urban albedo increases outdoor thermal comfort.

Impact of reflective materials on the street level microclimate



Impact on Air temperature and Mean radiant temperature

Increased reflectivity of the
TOP-HALF facades



! no impact on air temperature nor mean radiant temperature.

This could be an **effective strategy to increase UA** and potentially mitigate the UHI intensity at the urban scale **without compromising the street level microclimate.**

Conclusions

Evaluation of the ENVIMET IVS algorithm for radiation transfer :

- The algorithm showed a good agreement with measurements for reflections computation within urban canyons

Most effective strategies to increase urban albedo:

- **Increasing the reflectivity of roads** in low-rise urban canyons
- **Increasing the reflectivity of the top half of the canyon' facades** in high-rise urban canyons

Impact of reflective materials on street level microclimate:

- They increase the mean radiant temperature at street level, due to an increase of solar reflections
- This can be avoided by using reflective materials only on the top half part of the canyon façades

Economy and health aspects

- Economic aspects: reflective materials are a cost effective solution as they are relatively low cost and easy to apply to surfaces
- Health aspects: reflective materials can reduce overheating risk outside and reduce heat transfer to buildings thus reducing overheating inside.

References

1. Salvati A and Kolokotroni M (2020). *Impact of urban albedo on microclimate: Computational investigation in London.* 35th PLEA Conference, Sustainable Architecture and Urban Design, Planning Post Carbon Cities, A Coruna, Spain, 1-3 September 2020.

2. Salvati A and Kolokotroni M (2020). *Impact of urban albedo on microclimate and thermal comfort over a heat wave event in London.* Thermal Comfort Conference, WINDSOR 2020: Resilient Comfort in a Heating World, Cumberland Lodge, 16-19April 2020, Windsor UK. Pp566-578. https://windsorconference.com/proceedings/

What next? The UA project is developing An Urban Albedo Calculator to allow simple/rapid investigations of urban geometry and materials to control and improve microclimate

Thank you for listening!