Department of Meteorology

University of Reading

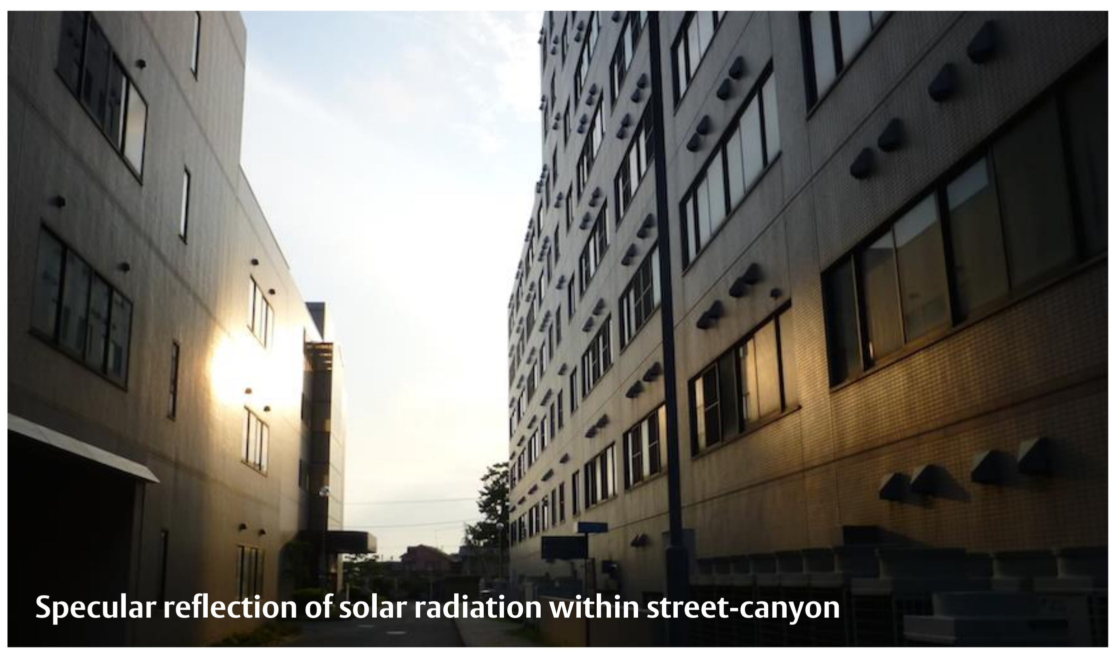
On the impact of surface heterogeneities on the radiative response of a simplified urban surface

Simone Kotthaus[1] | Atsushi Inagaki[2] | Fredrik Lindberg[3] | Sue Grimmond[1] | Manabu Kanda[2]

[1]University of Reading, UK; [2]Tokyo Institute of Technology, Japan; [3]University of Gothenburg, Sweden

Motivation

- Radiative response of the urban canopy is a function of 3D structure and material composition.
- Response usually assumed to be Lambertian.
- How important are specular reflections?
- How to best quantify local-scale radiation fluxes?
- What are the implications of sensor placement?



Albedo

- Albedo observed (Figure 3) depends on radiometer placement (Figure 4):

  local-scale > roof > canyon

- Roof/canyon albedo increases/decreases with lower sensor height
- Impact of direct vs. diffuse radiation differs with solar angle → long-term climatology required to derive robust albedo estimate

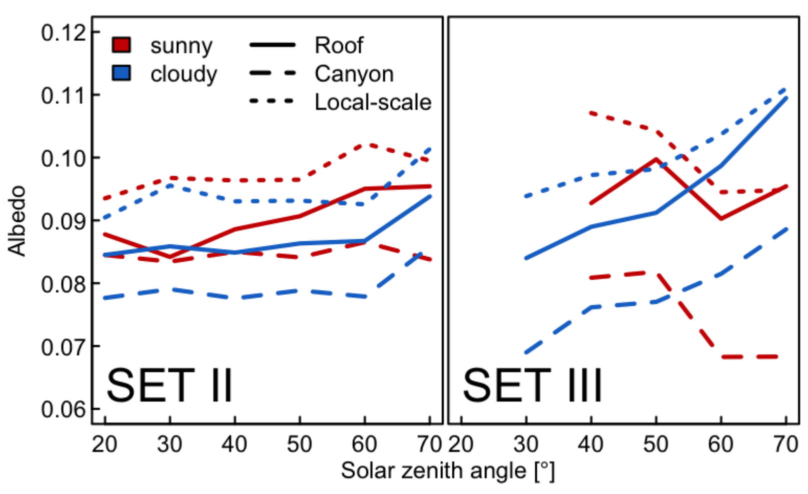


Figure 3 (left): Albedo by solar azimuth observed over roof (R1), canyon (R2) and at local-scale (R3) for sunny and cloudy conditions during SET II and SET III, respectively.

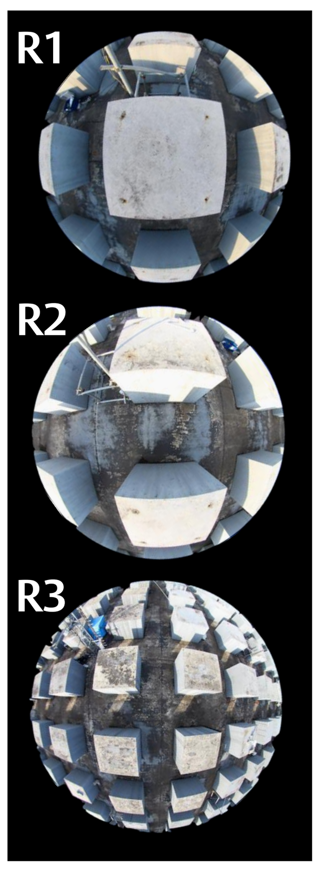


Figure 4: FOV of down-facing radiometers (SET III).

Measurement setup

- Observations performed June – September 2014
- At the Comprehensive Outdoor urban Scale MOdel Experiment for urban climate (COSMO, Figure 1), Kanda Laboratory, Tokyo Institute of Technology, *www.ide.titech.ac.jp/~kandalab/COSMO/COSMO.html*
- Observed variables include: incoming & outgoing long- & short-wave radiation fluxes, diffuse radiation, surface temperatures (used here; Table 1, Figure 2); air temperature profiles, wind and turbulent fluxes of sensible heat (see Inagaki et al. **POSTER 22: NOMTM**).
- Radiometer inter-comparison: shortwave good agreement; R1 & R2 offset in long-wave: correction determined against reference sensor
- High-reflectance aluminium sheets (Table 1)

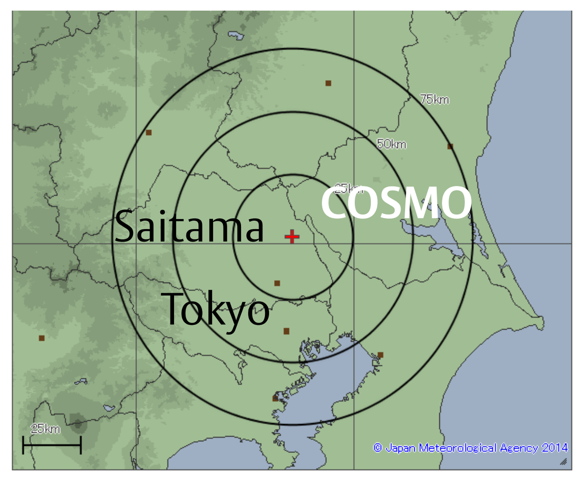


Figure 1: Location of COSMO site at Nippon Insti-tute of Technology, Saitama, Japan (36°01' N, 139°42' E)

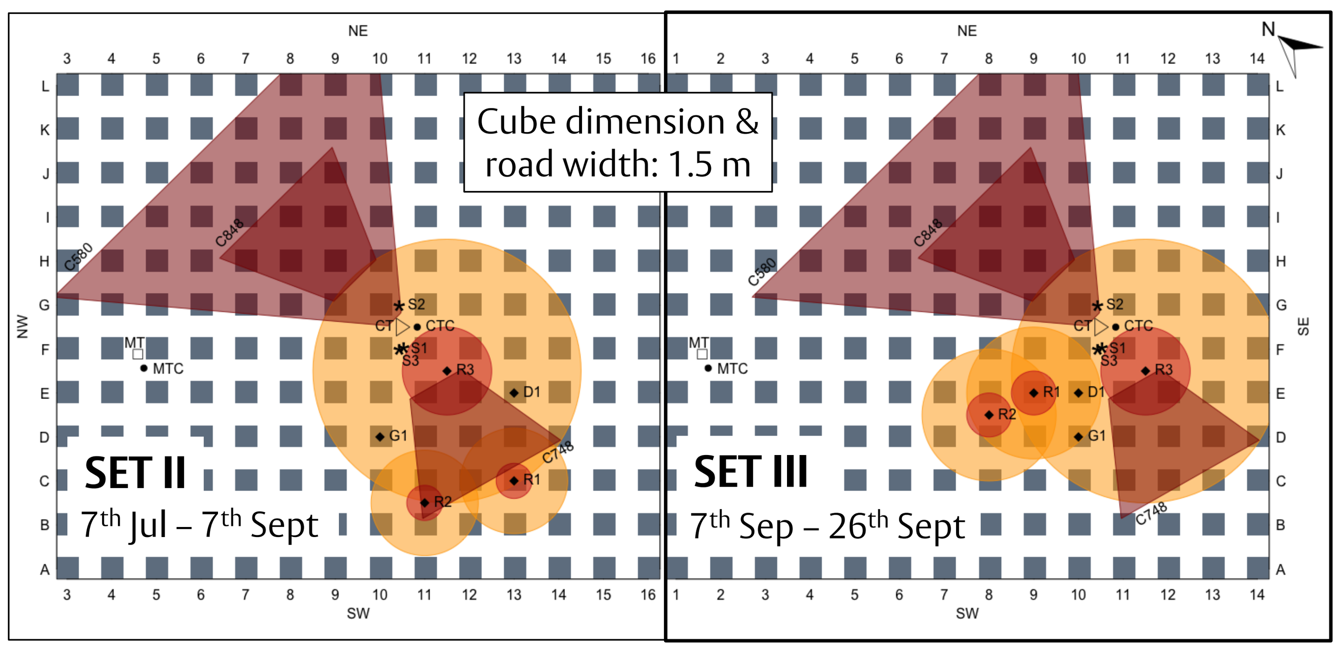


Figure 2 (right): Measurement setup at COSMO, top-view of (left) SET II & (right) SET III, with location markers (Δ : central tower, □ : mobile tower, ● : thermo-couple profiles, ♦: radiometers, ⁎ : sonic anemometers) and shading of source areas (dark red: IR imagers, yellow/orange: 80%/50% for down-facing radiometers).

Table 1: Instrumentation at COSMO in summer 2014 used in this study: sensor details and source area characteristics.

Code	Instrument	Manufacturer, Model	Specifications	Sensor height	Source area (Figure 2)	Aluminium sheet placement (case study days, block ID see Figure 2; R=roof; W/SE=wall)
R1	4 comp. radiometer	EKO Instruments, MR-40/ MR-50	305 – 2800 nm; 3 – 50 µm	SET II: 3.0 m a.g.l. SET III: 2.7 m a.g.l.	Roof	2nd Sept – 4th Sept: E9R, E8SW; 9th Sept – 17 Sept: C13R
R2					Canyon	2nd Sept – 4th Sept: D8R, D7SE; 9th Sept – 17 Sept: C11SW
R3				4.6 m a.g.l.	Local-scale	9th Sept – 17th Sept: E11SW, E11SE
C748	IR imager	Optris, PI-160	7.8 – 13 µm, 48° FOV	5 m a.g.l.	4-5 blocks	
C848				7 m a.g.l.		none

Surface temperatures

- Relation of surface brightness temperatures observed at different facets clearly depends on sun zenith angle
- Ground surfaces can reach temperatures comparable to roofs when zenith angle is high (Aug); south-west facing walls can exceed roof temperatures after noon when solar angle is low (Sept)
- Selection of sampling areas particularly critical for ground surfaces due to high contrast between shaded & sunlit areas

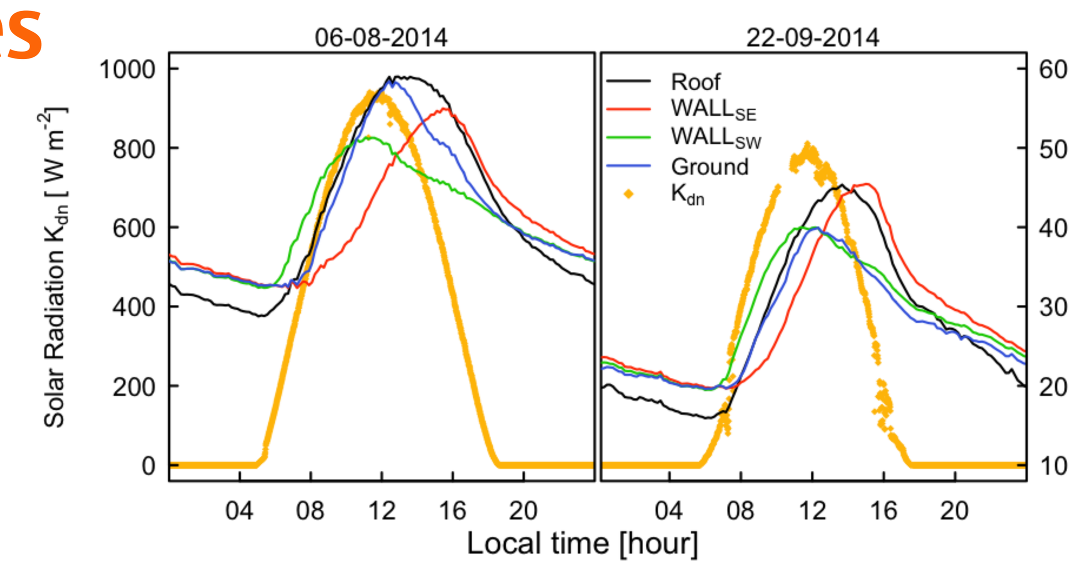


Figure 5 (top): Observed incoming solar radiation K_{dn} and brightness temperatures of selected areas (see Figure 6) within FOV of IR imager C848 (Table 1, Figure 2), on two mostly clear-sky case-study days; 1 min data averaged to 10 min.

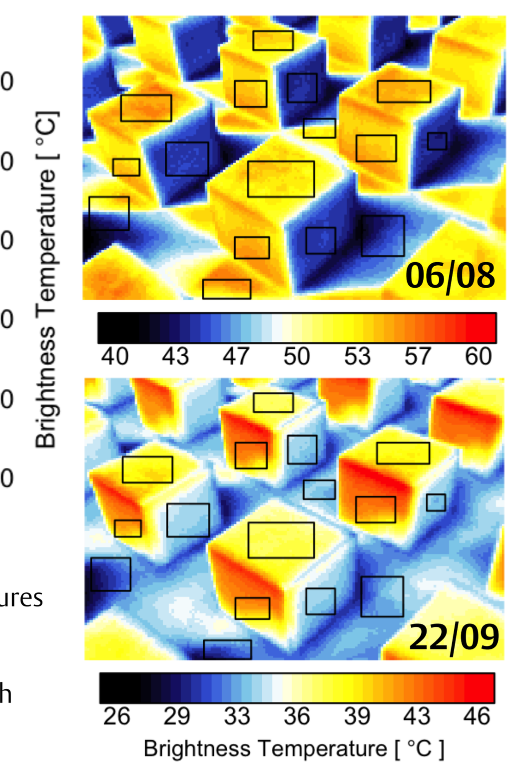
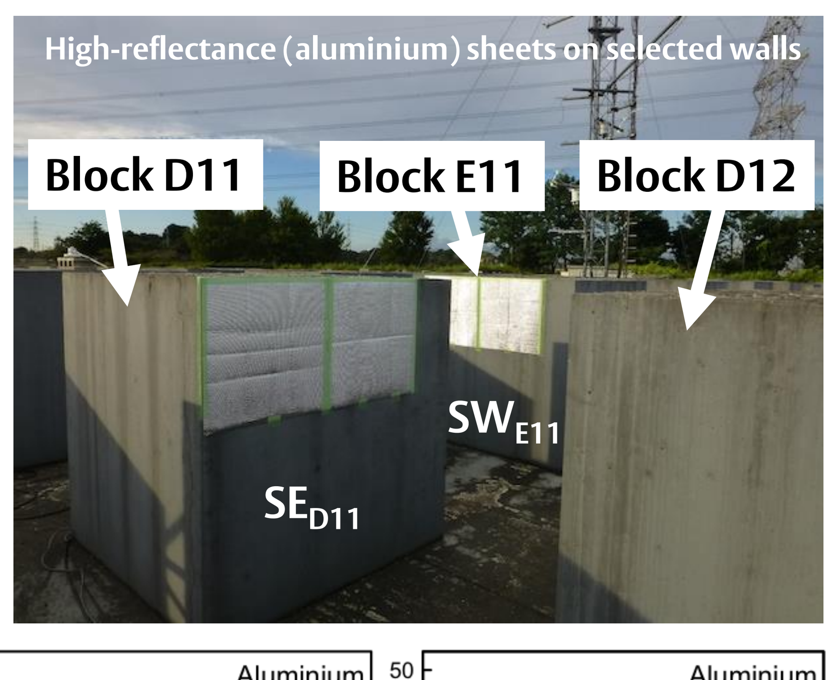


Figure 6 (right): Brightness temperatures observed by IR imager C848 (Table 1, Figure 2), on two case study days (see Figure 5) at 16:00 JST (local time), with sampling areas used for Figure 5.

Case study: high-reflectance materials

- High-reflectance aluminium sheets installed in source area of radiometers and IR imager (Table 1)
- **Aluminium on roof**: strong increase in albedo for both sunny and cloudy conditions; **aluminium on wall**: less obvious – potentially small increase observed with canyon radiometer if sheets on south-facing walls (SET II)
- NE (NW) facing walls opposing SW (SE) facing walls with aluminium cover show clearly increased brightness temperatures during early afternoon (morning) by up to ~ 2 °C



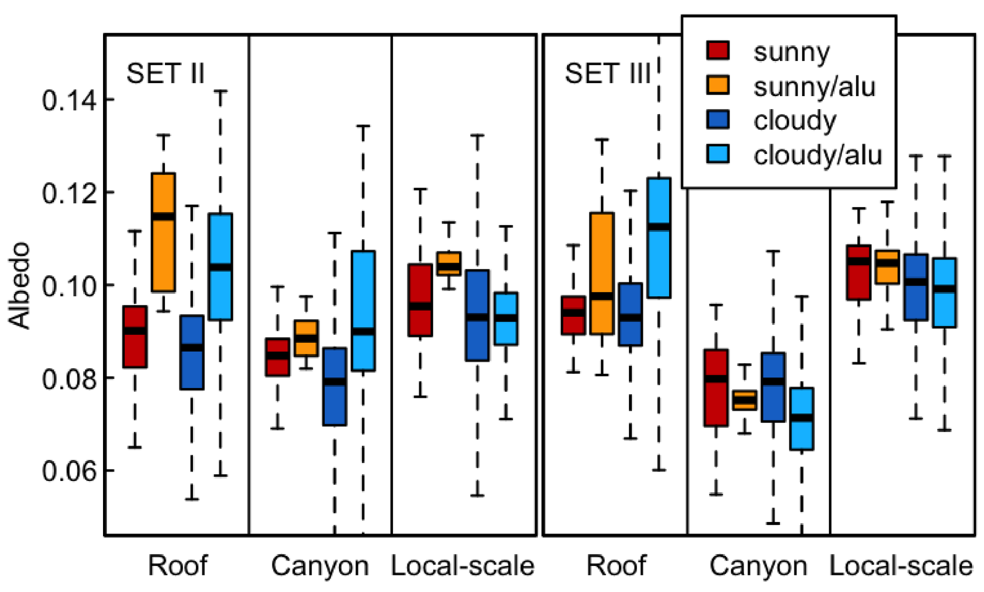


Figure 7 (left): Albedo by solar azimuth observed over roof (R1), canyon (R2) and at local-scale (R3) for sunny and cloudy conditions during SET II and SET III, respectively.

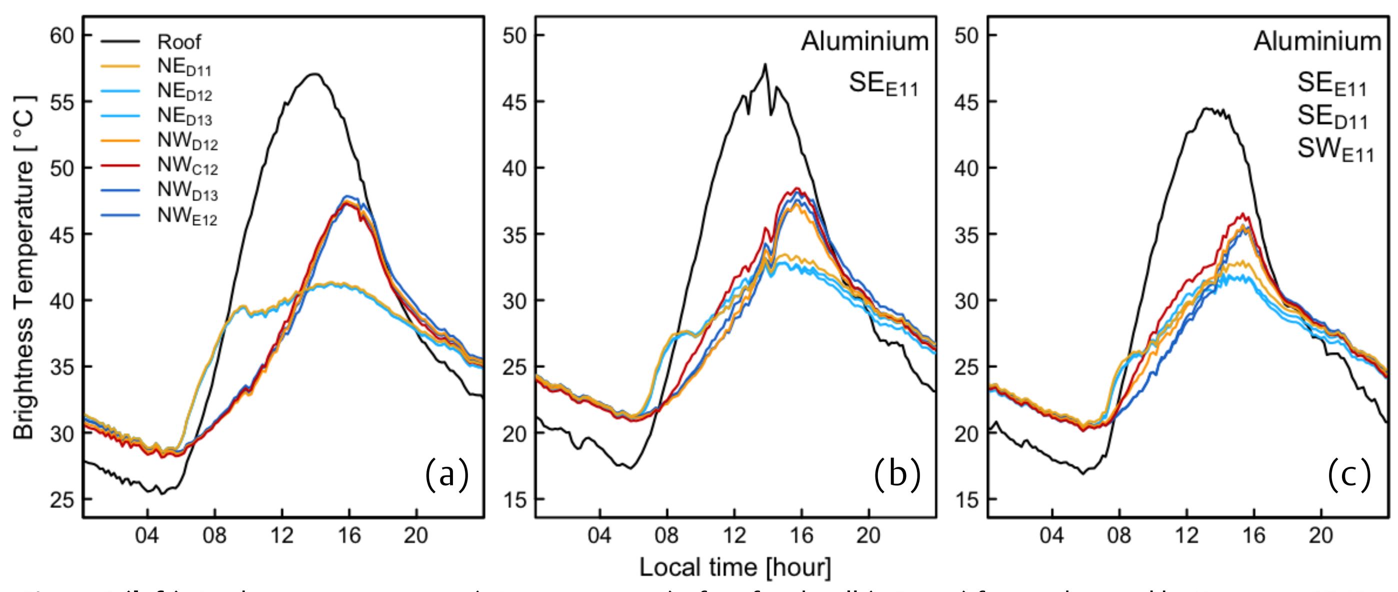


Figure 8 (left): Brightness temperature (10 min averages) of roof and wall (NE, NW) facets observed by IR imager C748 (Table 1, Figure 2) on three clear-sky days with (a) no, (b) one and (c) three aluminium sheets placed on selected walls.

Conclusions

- Long-term observations required to accurately characterise radiative response as 3D surface morphology introduces high sun-angle dependence
- High-reflectance materials impact not only surface albedo but may also increase surface temperatures of facets receiving the reflected energy
- Variations in surface geometry and material composition can clearly impact local-scale storage heat flux and potentially the energy balance of buildings and the overlying air

Outlook

- Further quality control and data analysis
- Use radiation models (e.g. SOLWEIG, Lindberg et al. 2008) to evaluate the impact of surface heterogeneities on the radiative response at different scales

Acknowledgements

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References

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Contact information

- Department of Meteorology, University of Reading, Whiteknights, RG6 6AH
- Email: s.kotthaus@reading.ac.uk