Pyranometers and pyrgeometers to measure all four components of the radiation balance (Photo: A. Christen)

08 Net all-wave radiation

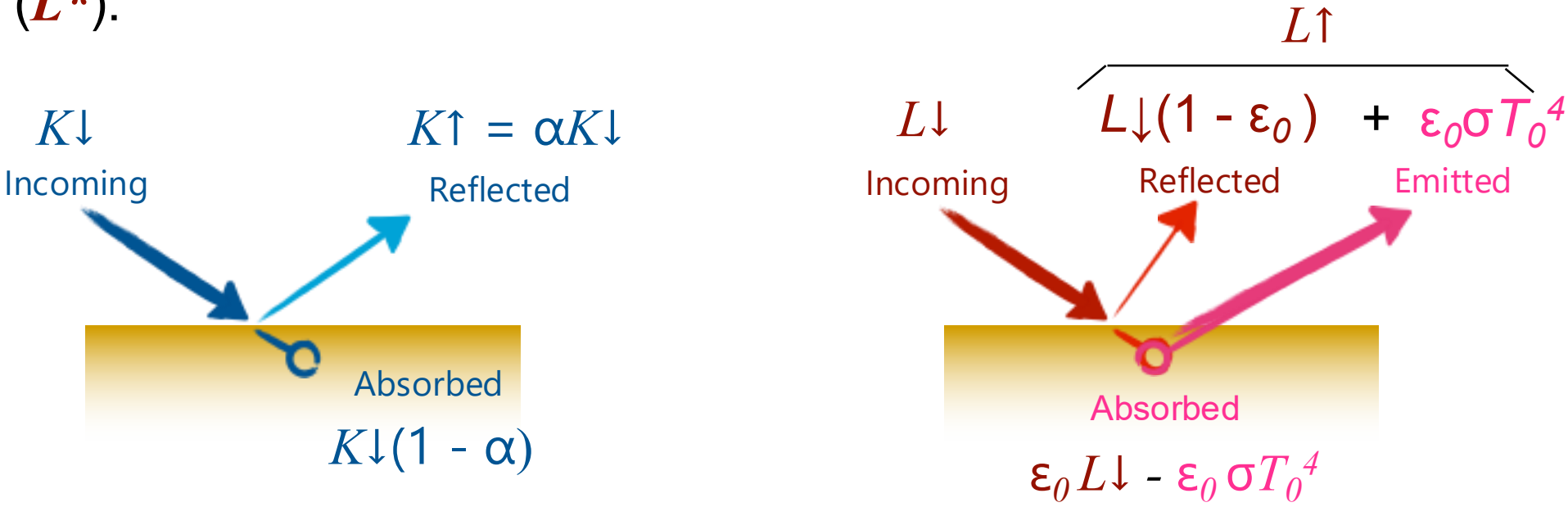
Learning objectives

- Be able to formulate the net-effect of all radiative exchange processes for surfaces.
- Describe which surface and geometric properties control radiative exchange.
- Be able to interpret graphs/figures of net-radiative exchange over diurnal and annual scales.

Photo: A. Christen

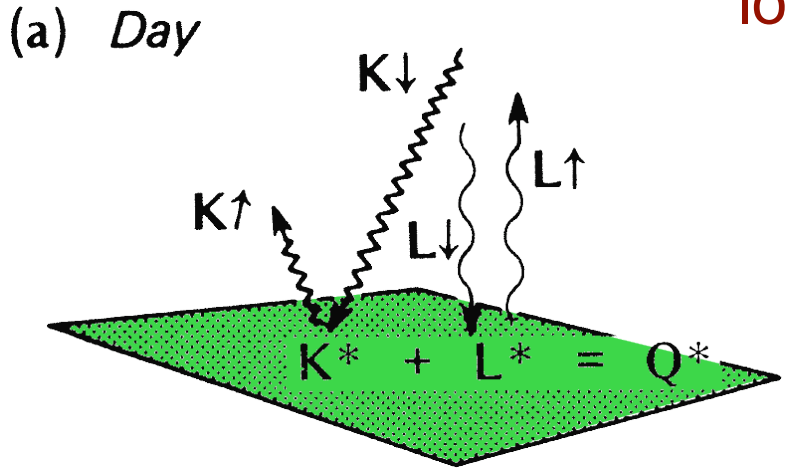
Net short-wave and net long-wave

Net all-wave radiation (Q^*) of a surface is the sum of the **net short-wave radiation** (K^*) and **net long-wave radiation** (L^*):



Absorbed : available energy for other processes

Net radiation for a flat surface



Net all-wave radiation (Q^*) is the sum of the net short-wave radiation (K^*) and net long-wave radiation (L^*):

$$K^* = K\downarrow - K\uparrow$$
$$= K\downarrow(1 - \alpha) \quad \bigstar$$

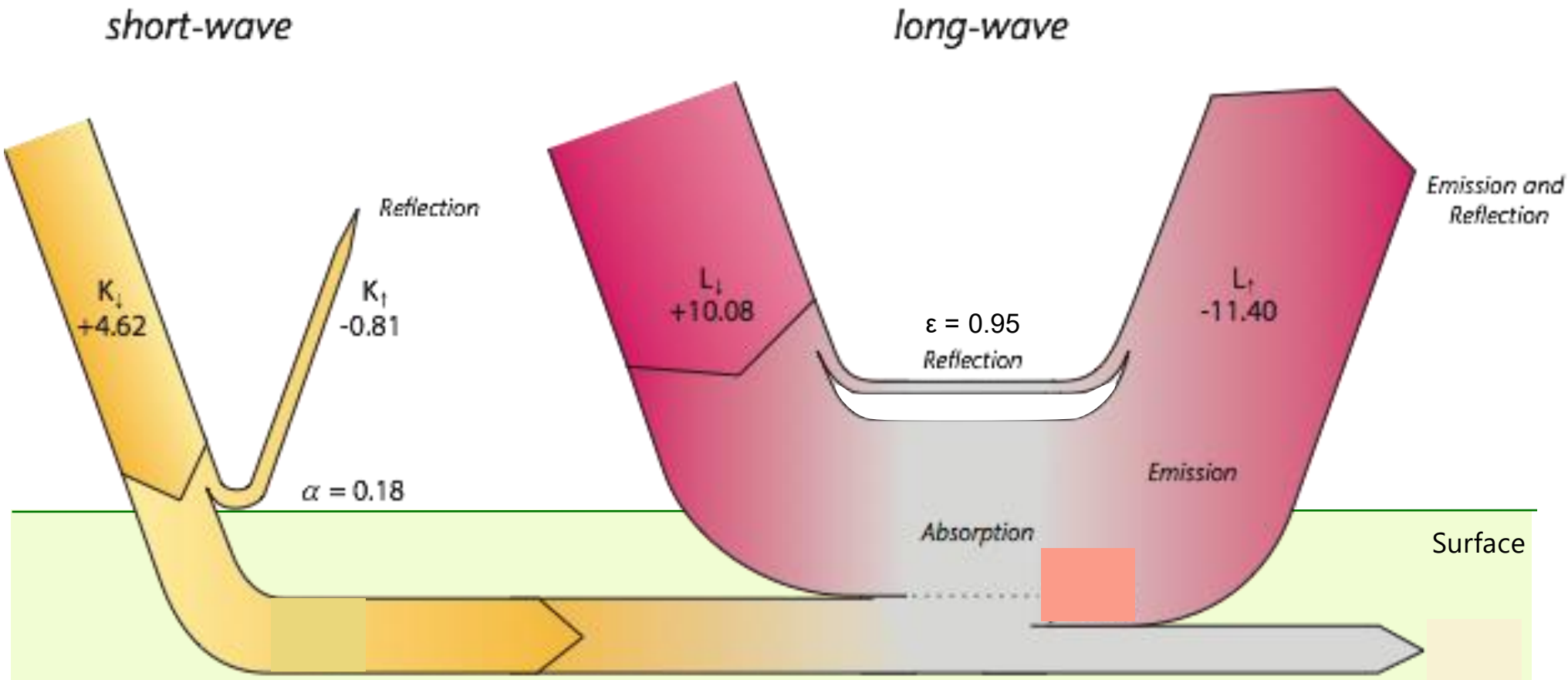
$$L^* = L\downarrow - L\uparrow$$
$$= L\downarrow - [\varepsilon_o \sigma T_o^4 + L\downarrow(1 - \varepsilon_o)]$$

$$Q^* = K^* + L^*$$
$$= K\downarrow(1 - \alpha) + \varepsilon_o L\downarrow - \varepsilon_o \sigma T_o^4 \quad \bigstar$$

absorbed absorbed emitted

T.R. Oke (1987): 'Boundary Layer Climates' 2nd Edition.

Surface radiation balance over grass in Vancouver



Westham Island, Delta, BC

all values in GJ m^{-2} $year^{-1}$

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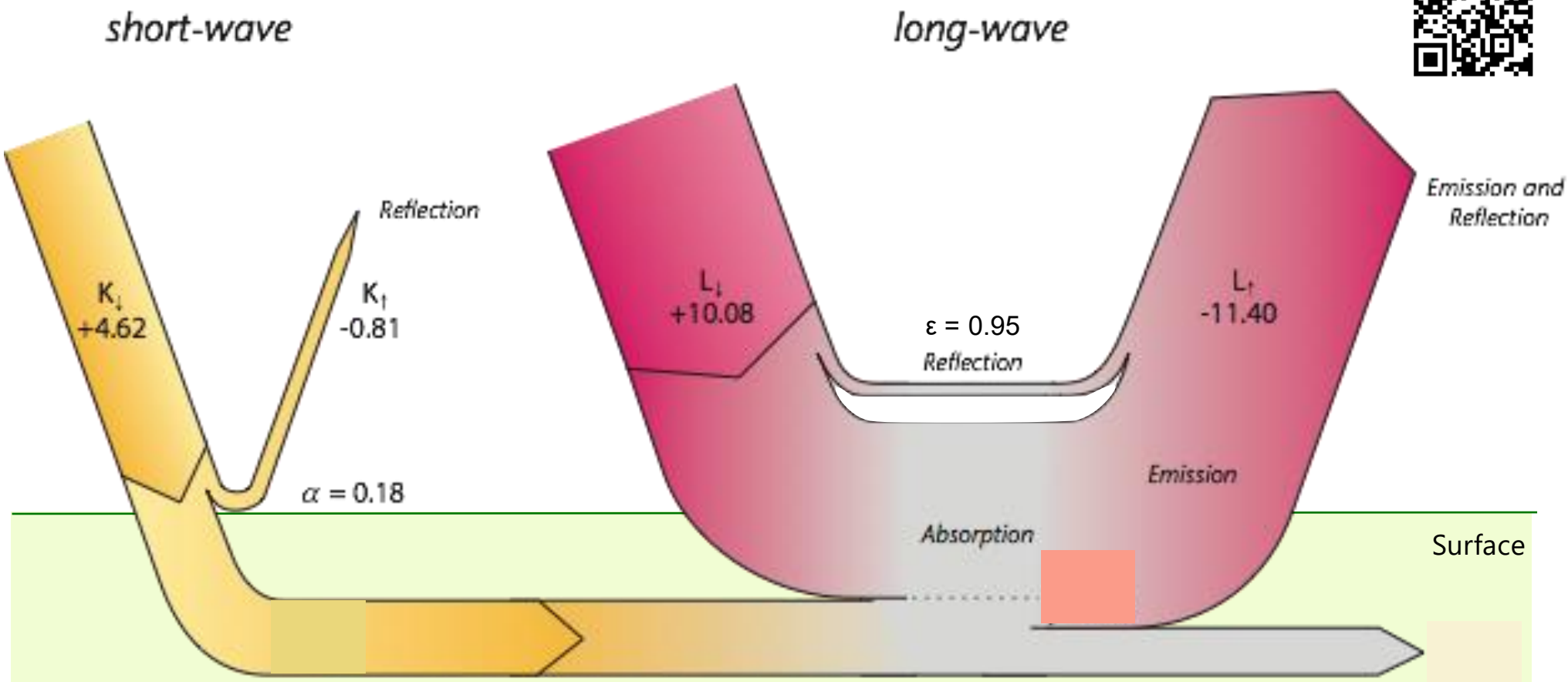
What is the net radiation balance for Vancouver?



Westham Island, Delta, BC

all values in GJ m^{-2} $year^{-1}$

Handout activity

The importance of surface properties of land-surfaces

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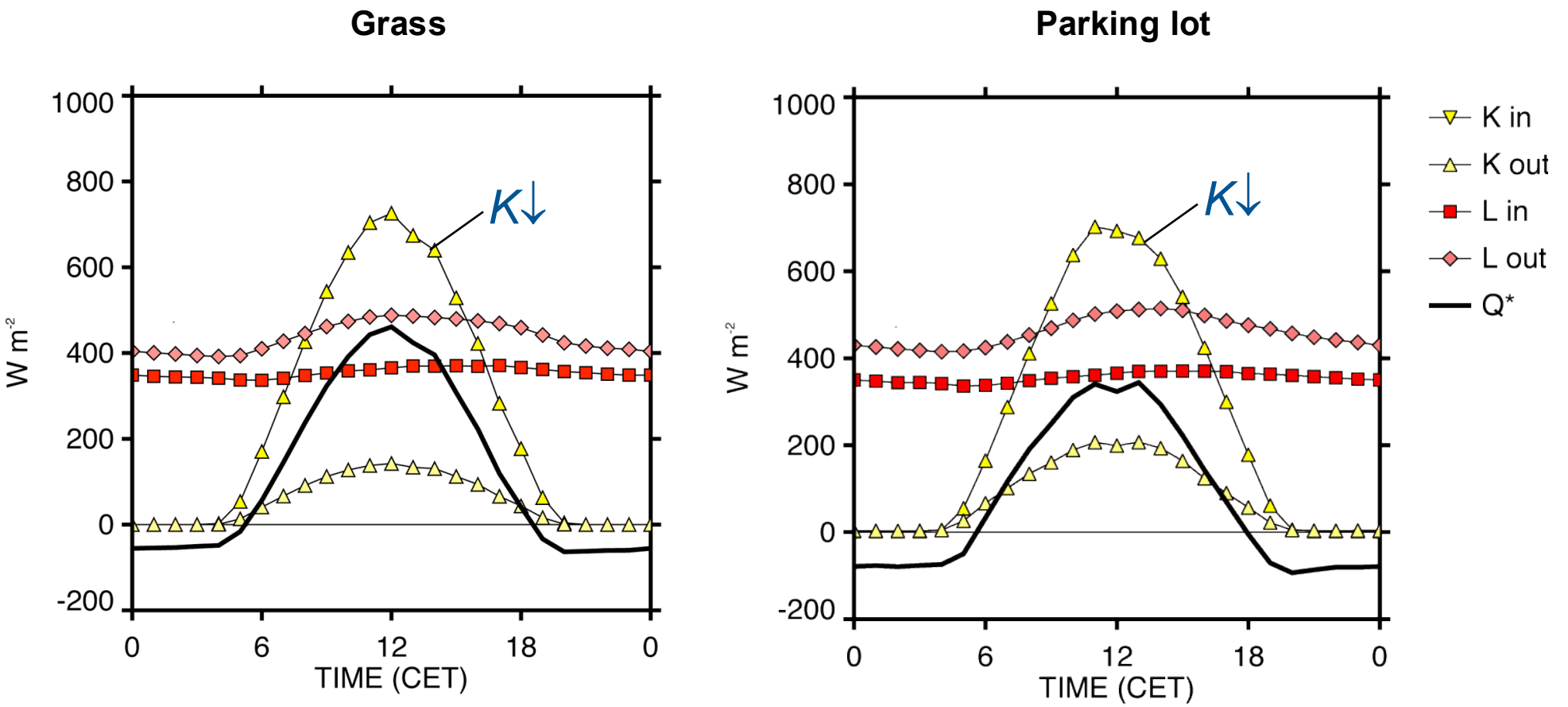
$$K\downarrow(1 - \alpha) + \varepsilon_o L\downarrow - \varepsilon_o \sigma T_o^4$$

Which are the surface properties that impact Q*?
Which are the inputs of radiation?

The range of values is lessened by the fact that the effects of α and T_o tend to partially offset each other.

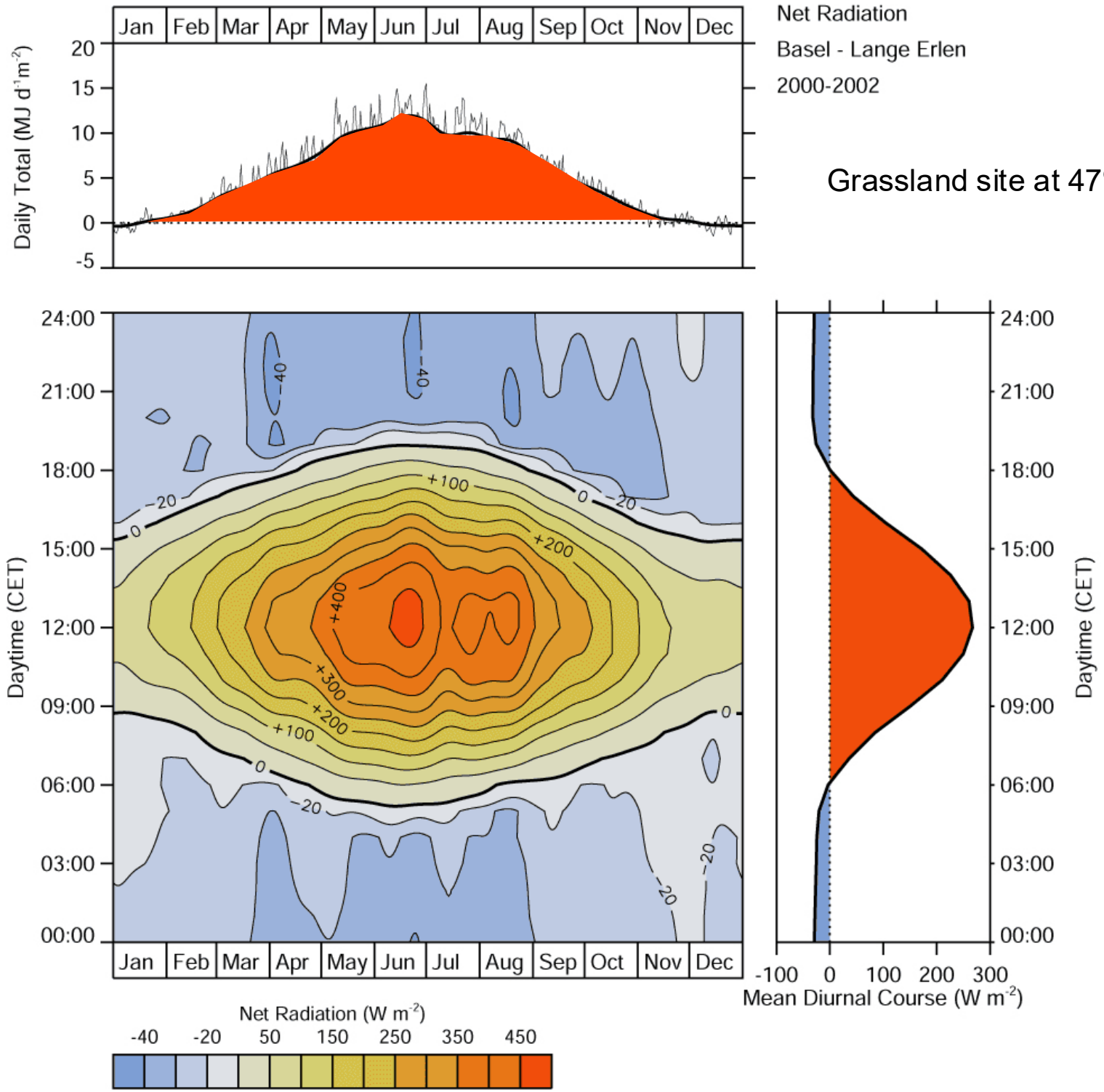
Clouds reduces extremes because they decreases $K\downarrow$ and increases $L\downarrow$.

Simultaneously measured Q* - different surface properties



Q* =12.6 MJ m^{-2} day^{-1}

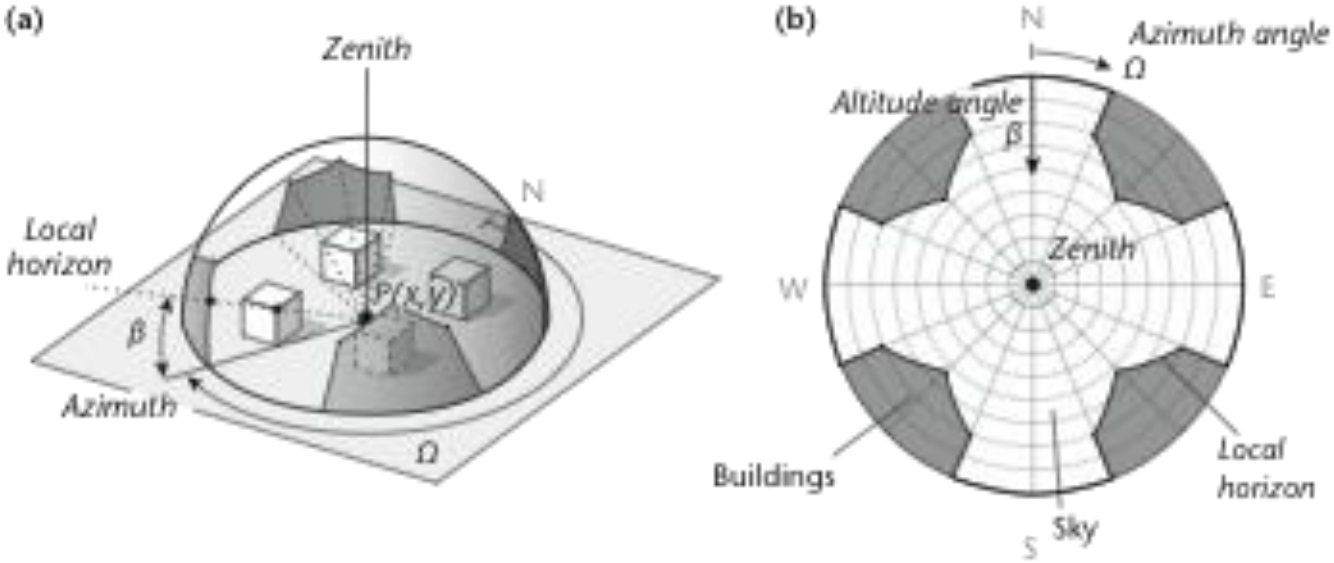
Q* =6.4 MJ m^{-2} day^{-1}


Net Radiation
Basel - Lange Erlen
2000-2002
Daily Total (MJ d-1m-2)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
20 15 10 5 0 -5
Grassland site at 47° N
Daytime (CET)
24:00 21:00 18:00 15:00 12:00 09:00 06:00 03:00 00:00
-40 -20 0 +100 +200 +300 +400
Mean Diurnal Course (W m-2)
-100 0 100 200 300
Net Radiation (W m-2)
-40 -20 50 150 250 350 450

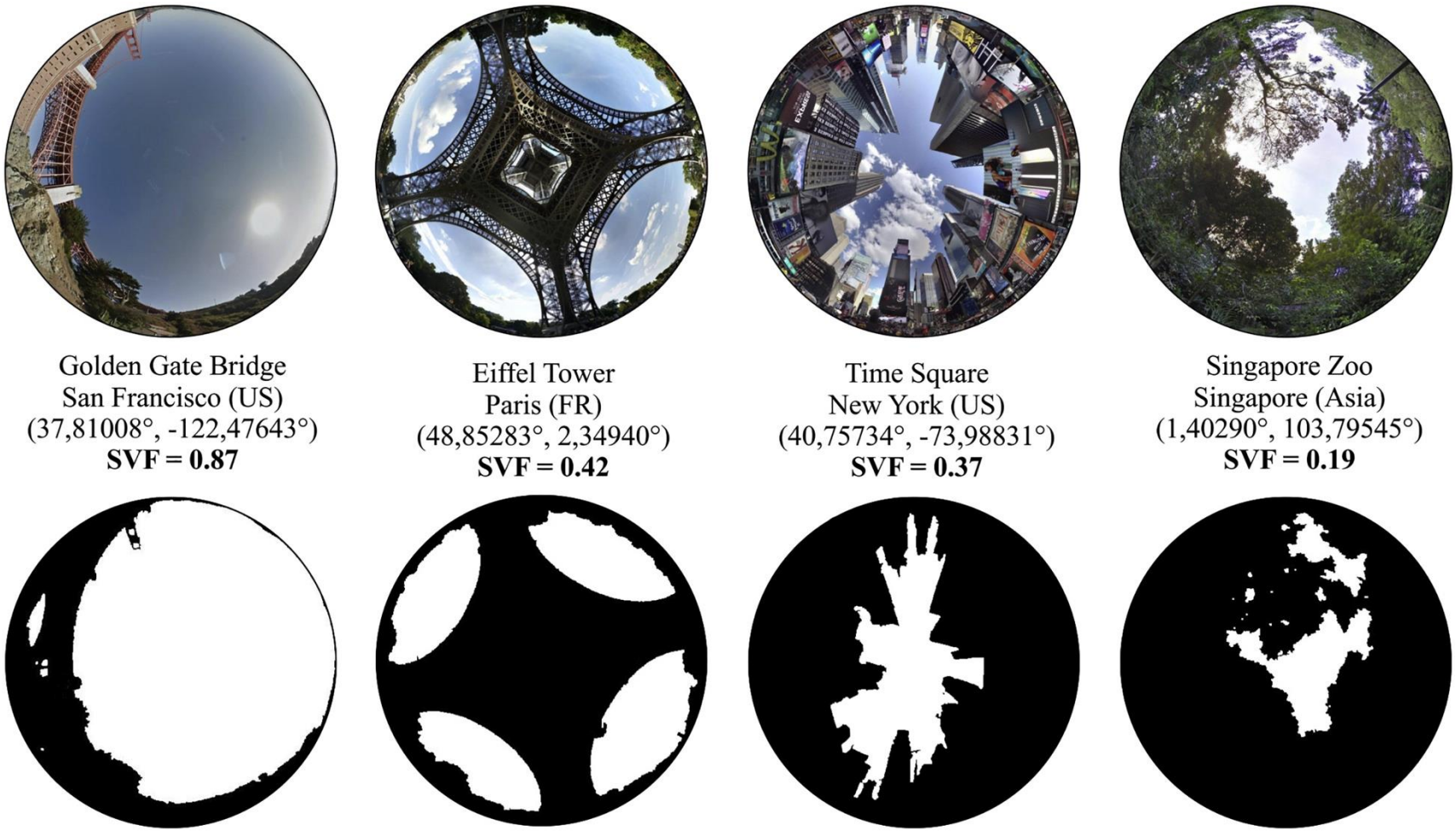
View factors

A View factor refers to the fraction of radiation leaving one object that is intercepted by another object.

- Can be interpreted as fraction of one object's view (usually hemispherical) that is occupied by another object.
- The view of the sky from an object (**sky view factor**, ψ_{sky}) is significant in quantifying long-wave exchange in complex configurations:



Examples of sky view factors



Golden Gate Bridge
San Francisco (US)
(37,81008°, -122,47643°)
SVF = 0.87

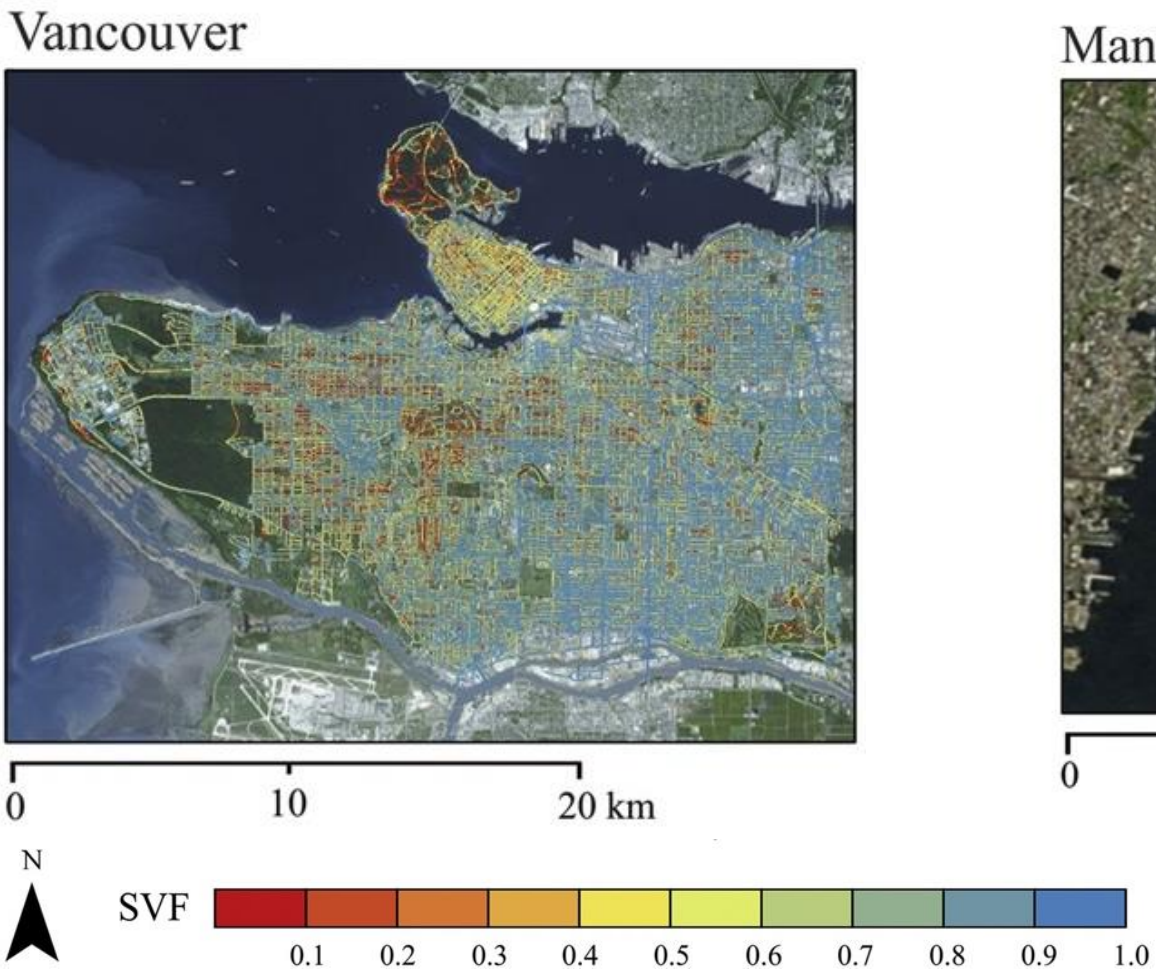
Eiffel Tower
Paris (FR)
(48,85283°, 2,34940°)
SVF = 0.42

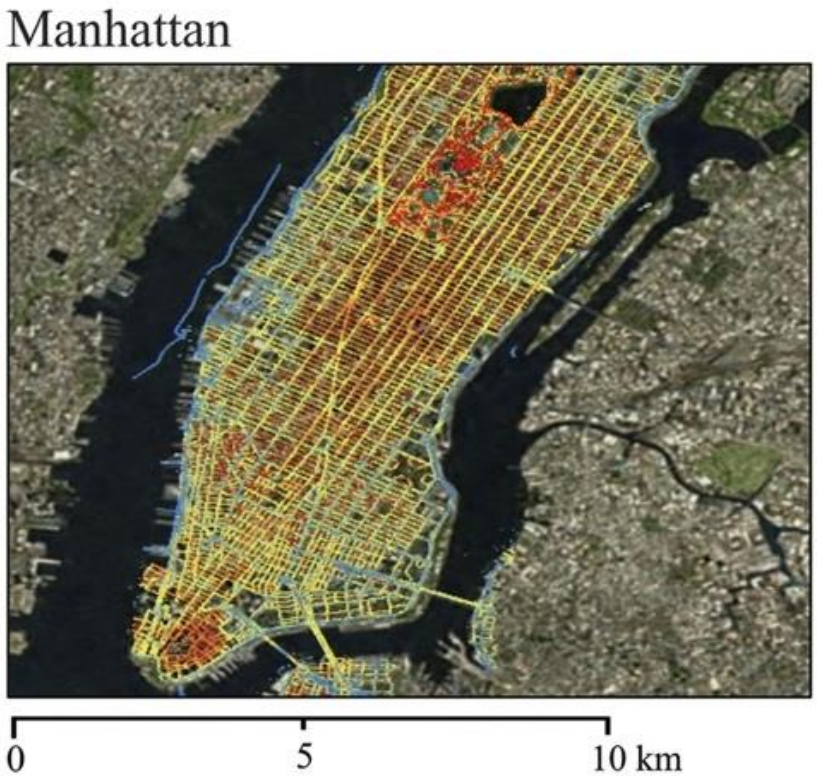
Time Square
New York (US)
(40,75734°, -73,98831°)
SVF = 0.37

Singapore Zoo
Singapore (Asia)
(1,40290°, 103,79545°)
SVF = 0.19

Middel et al. (2018) Urban Climate

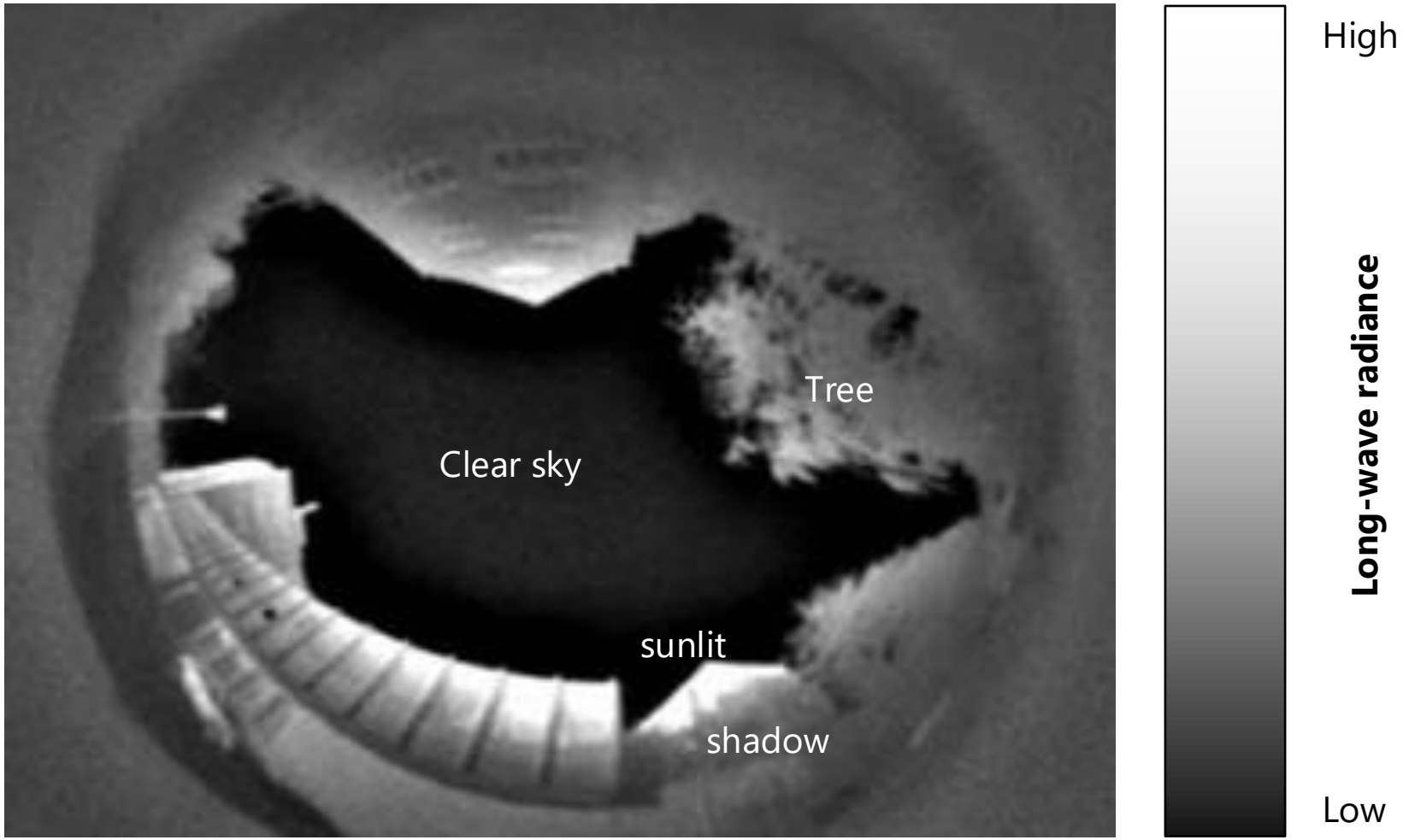
Differences across major cities





Middel et al. (2018) Urban Climate

Thermal infrared through a fish-eye lens



Chapman, L., Thornes, J.E., Muller, J.P. & McMuldroch, S. (2007) Potential applications of thermal fisheye imagery in urban environments. *Geoscience and Remote Sensing Letters* 4(1): 56-59

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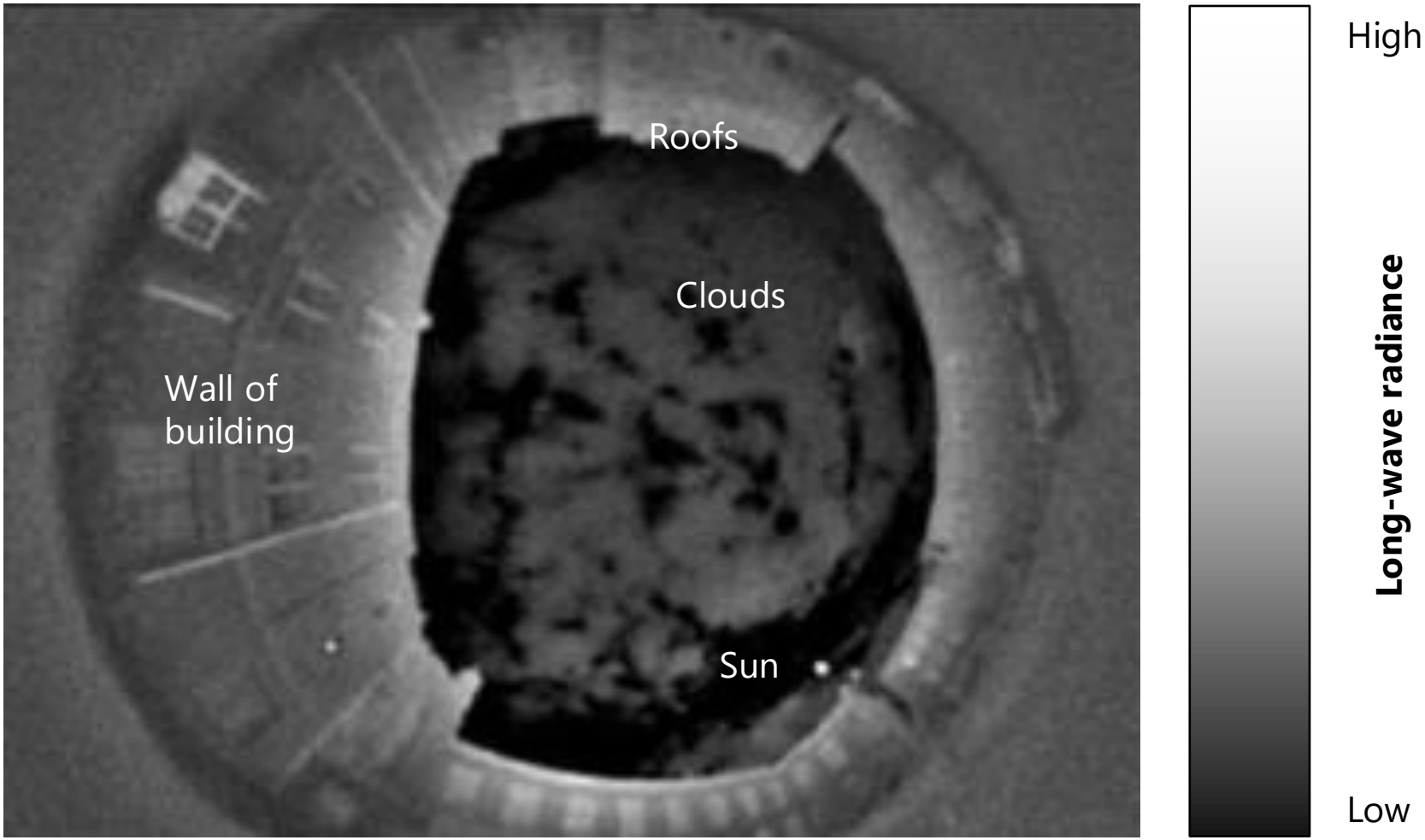

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Geometry control

Photo: A. Christen

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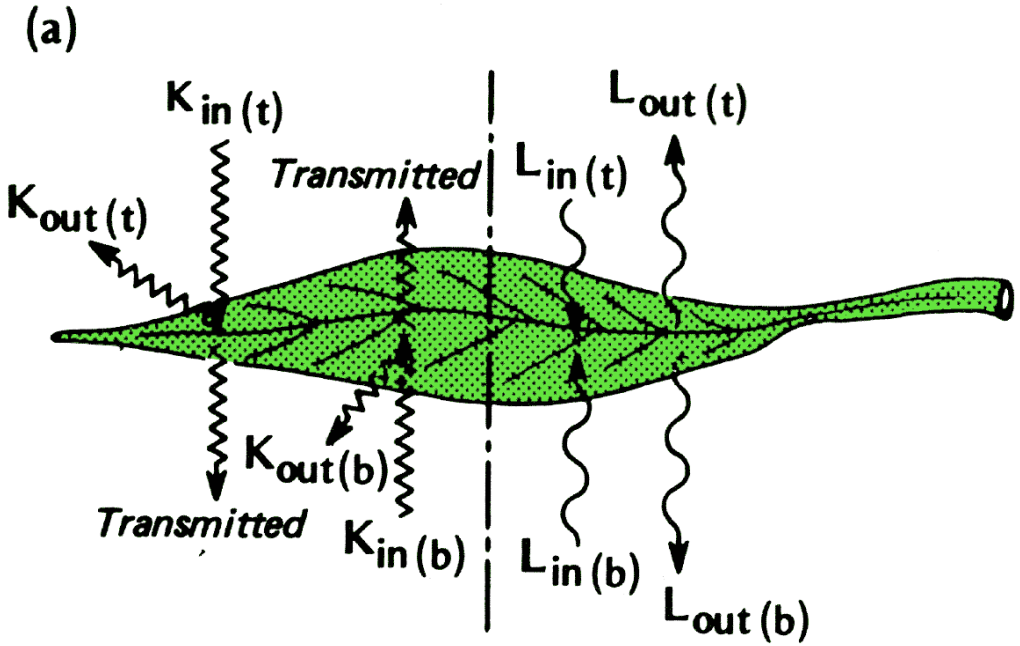
Net radiation of two-sided object

A leaf is a 2-sided object so the simple incoming (↓) and outgoing (↑) consideration for the ground is insufficient - this has to be done on both sides, top (t) and bottom (b), and transmission is relevant:



T.R. Oke (1987): 'Boundary Layer Climates' 2nd Edition, with permission by author

$$Q^* = K^* + L^*$$

$$K^* = K_{in}(t) + K_{in}(b) - K_{out}(t) - K_{out}(b) - K_{trans}(t) - K_{trans}(b)$$

$$L^* = L_{in}(t) + L_{in}(b) - L_{out}(t) - L_{out}(b)$$

Take home points

- Surface properties in the net all-wave budget tend to partially offset each other - in particular albedo and surface temperature.
- Temporal and spatial differences in net all-wave radiation are controlled by the distribution of **short-wave irradiance**, **atmospheric conditions** (clouds) and **surface properties**.
- Net all-wave radiative exchange of two-sided and 3D objects needs to consider distributions of radiative fluxes surrounding the object.