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.

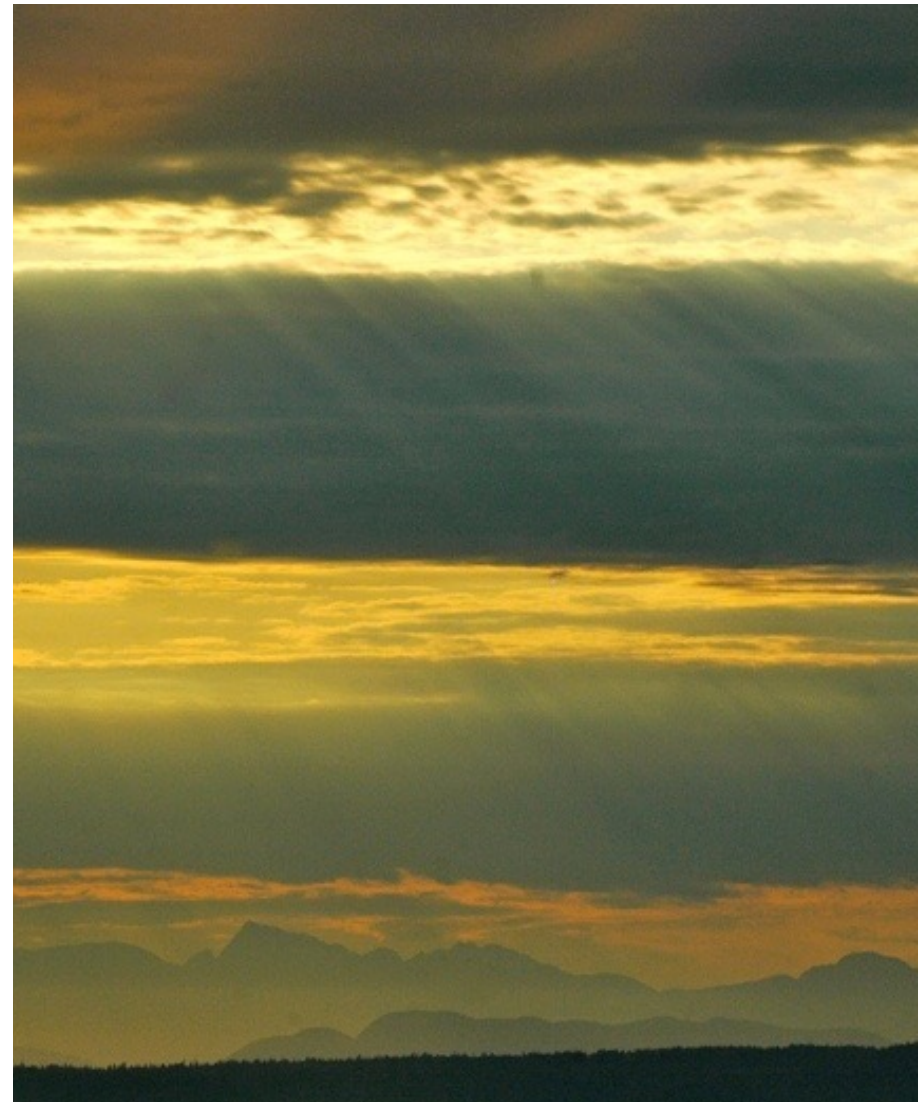
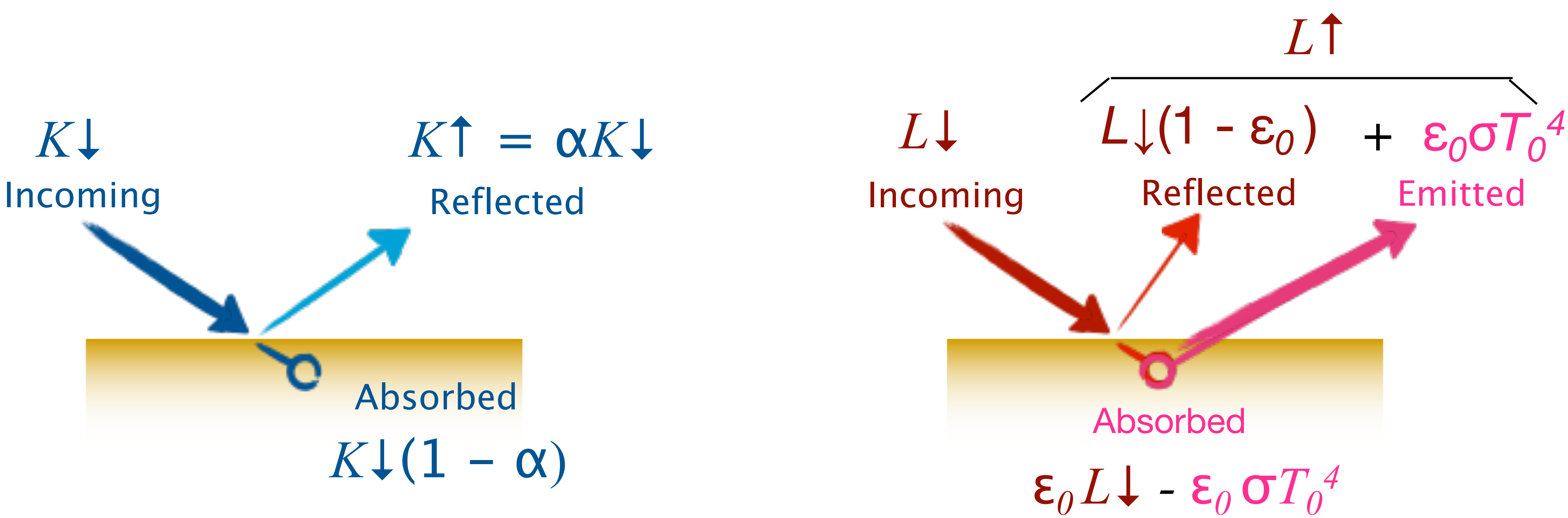


Photo: A. Christen

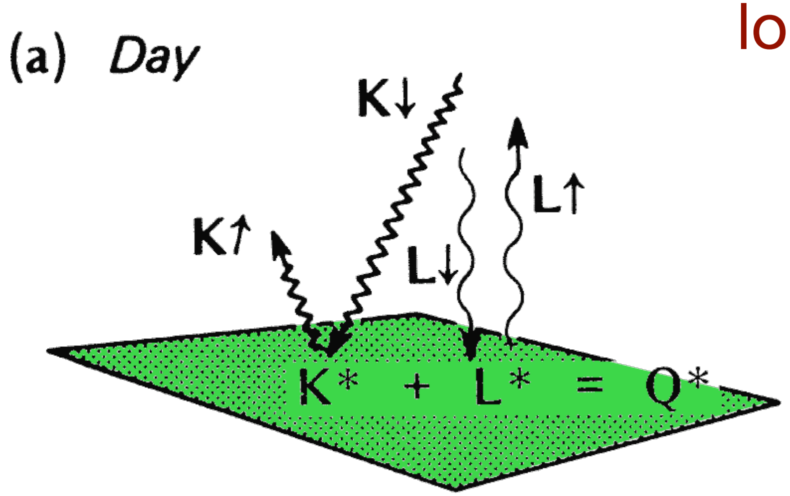
Net short-wave and net long-wave

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**):

$$K^* = K{\downarrow} - K{\uparrow}$$
$$= K{\downarrow}(1 - \alpha) \quad ★$$

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

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

absorbed absorbed emitted

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

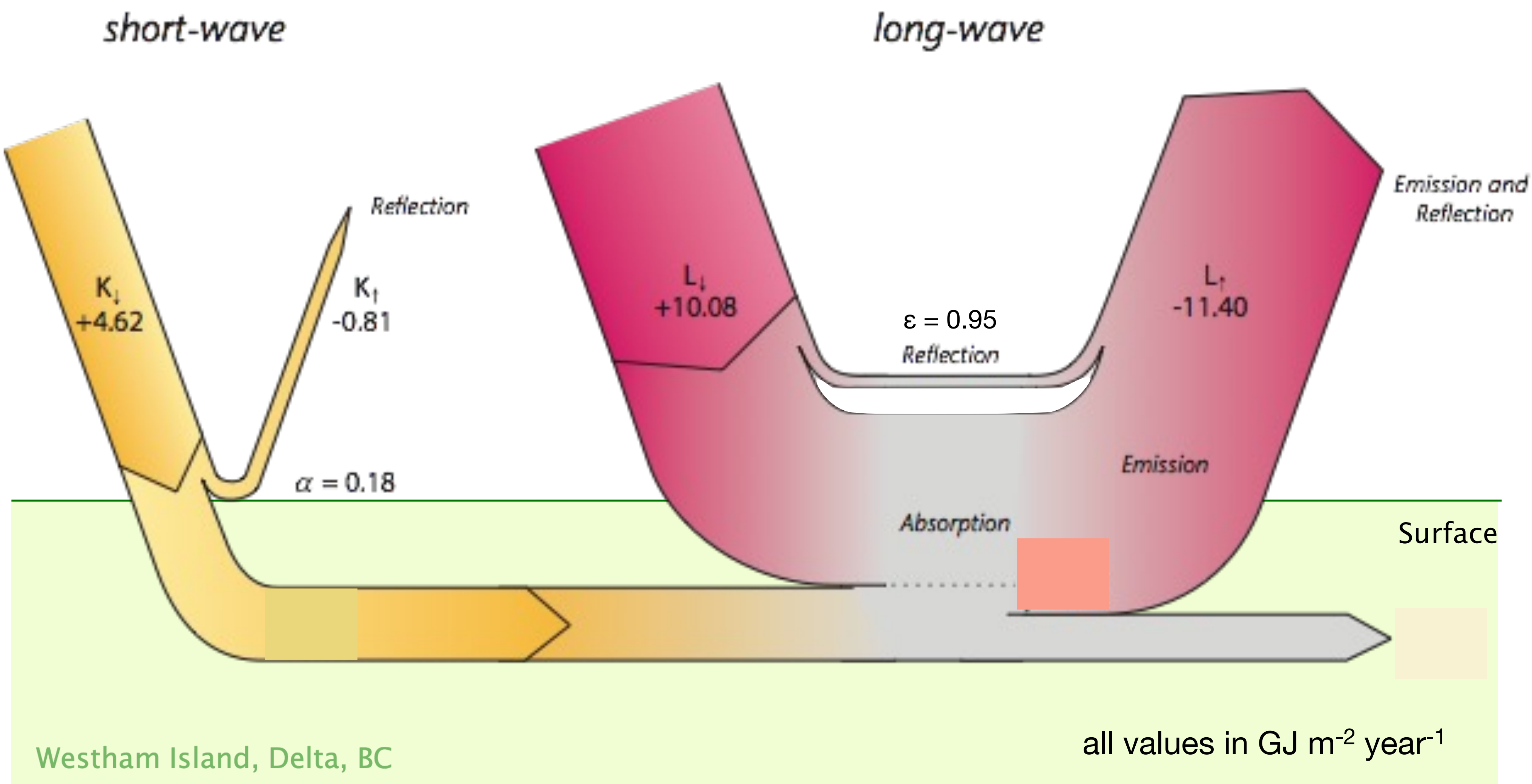
Handout activity

Topic 8 – Net all-wave radiation

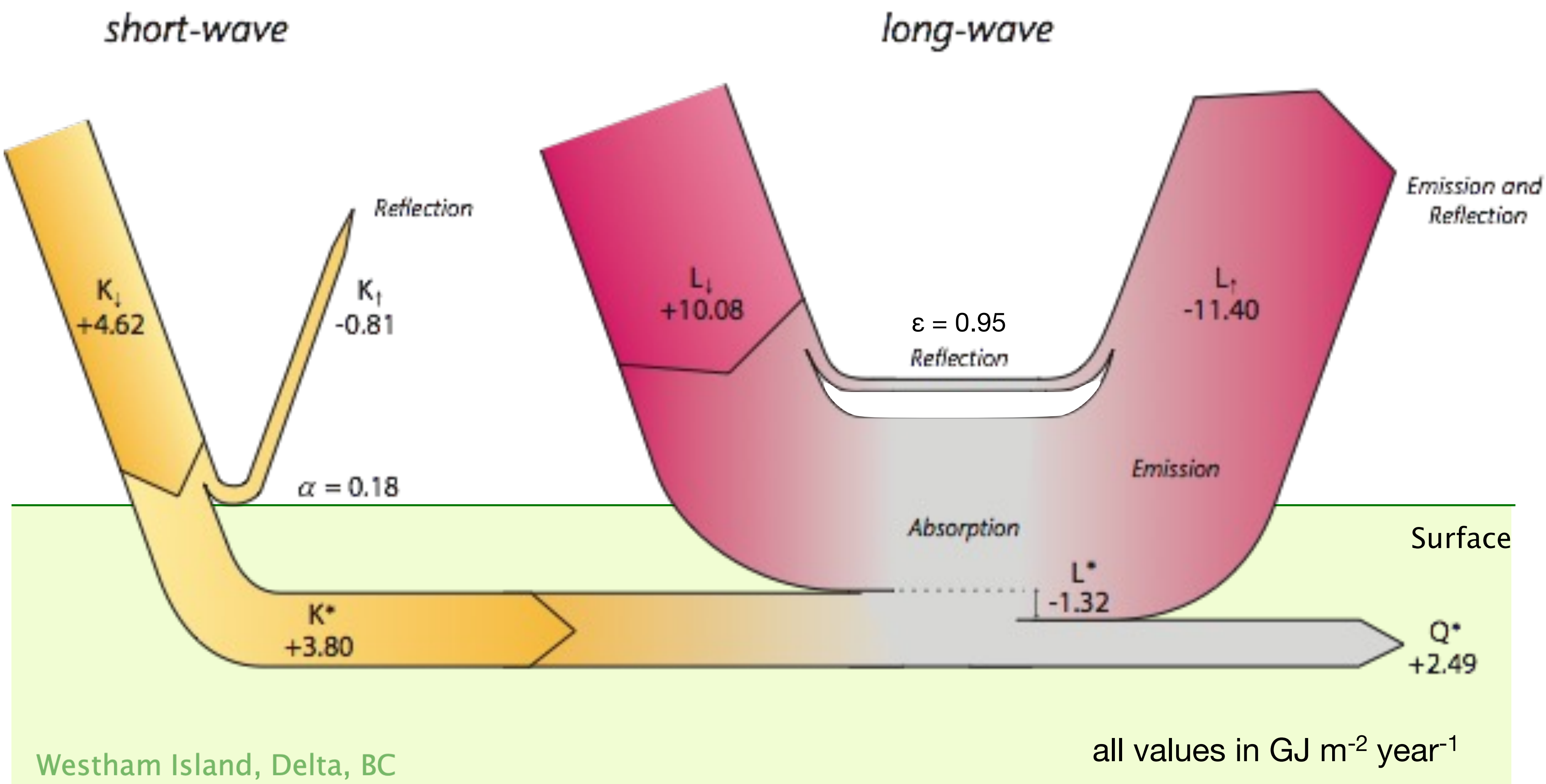
1. Match the variable with the symbol/equation:

Variable	**Symbol/Equation**
Incoming shortwave radiation	$K\downarrow$
Reflected shortwave radiation	$K\uparrow = \alpha K\downarrow$
Absorbed shortwave radiation	$K\downarrow(1 - \alpha)$
Incoming longwave radiation	$L\downarrow$
Outgoing longwave radiation	$L\uparrow = L\downarrow(1 - \varepsilon_0) + \varepsilon_0 \sigma T_0^4$

Surface radiation balance over grass in Vancouver



Surface radiation balance over grass in Vancouver



The importance of surface properties of land-surfaces (Slido)

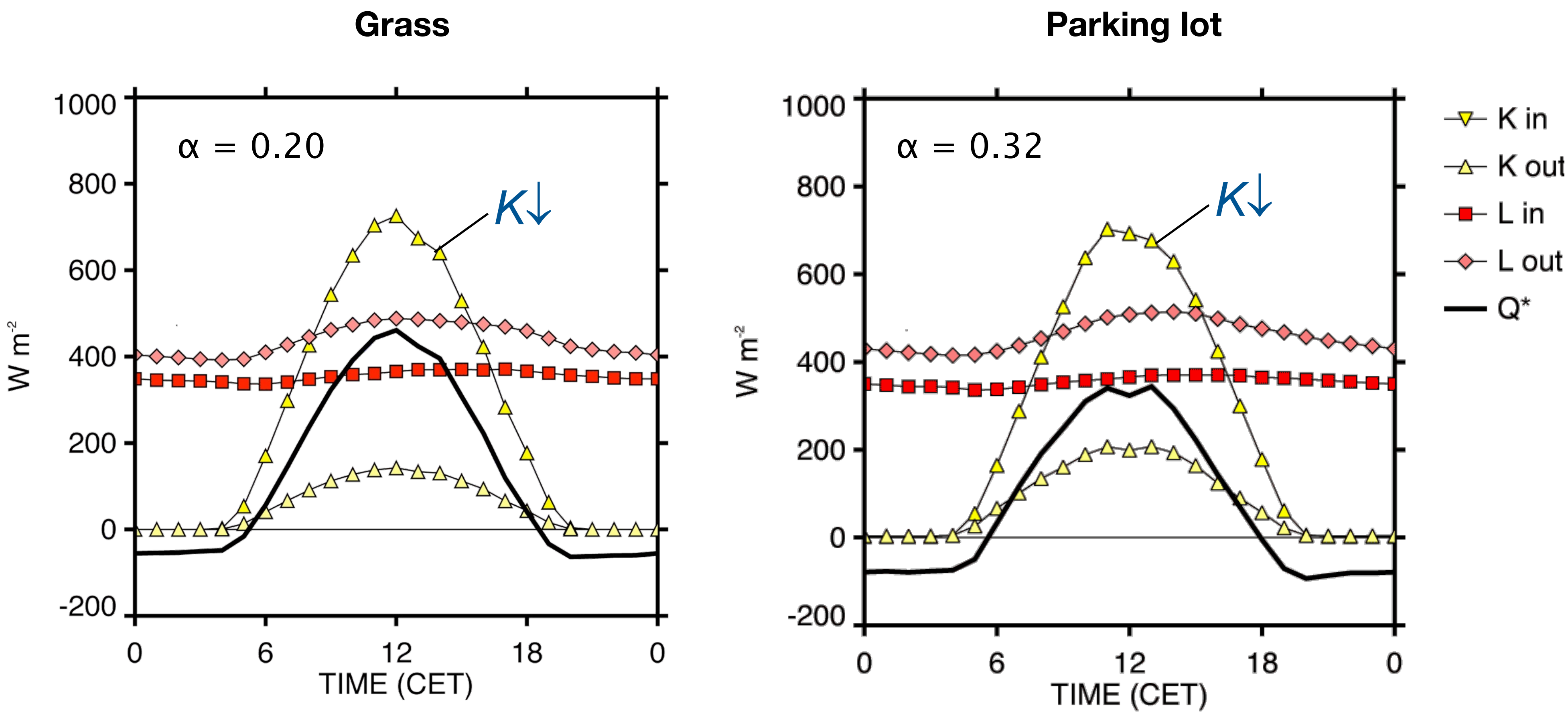
$$K{\downarrow}(1 - \alpha) + \varepsilon_o L{\downarrow} - \varepsilon_o \sigma T_o^4$$

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.

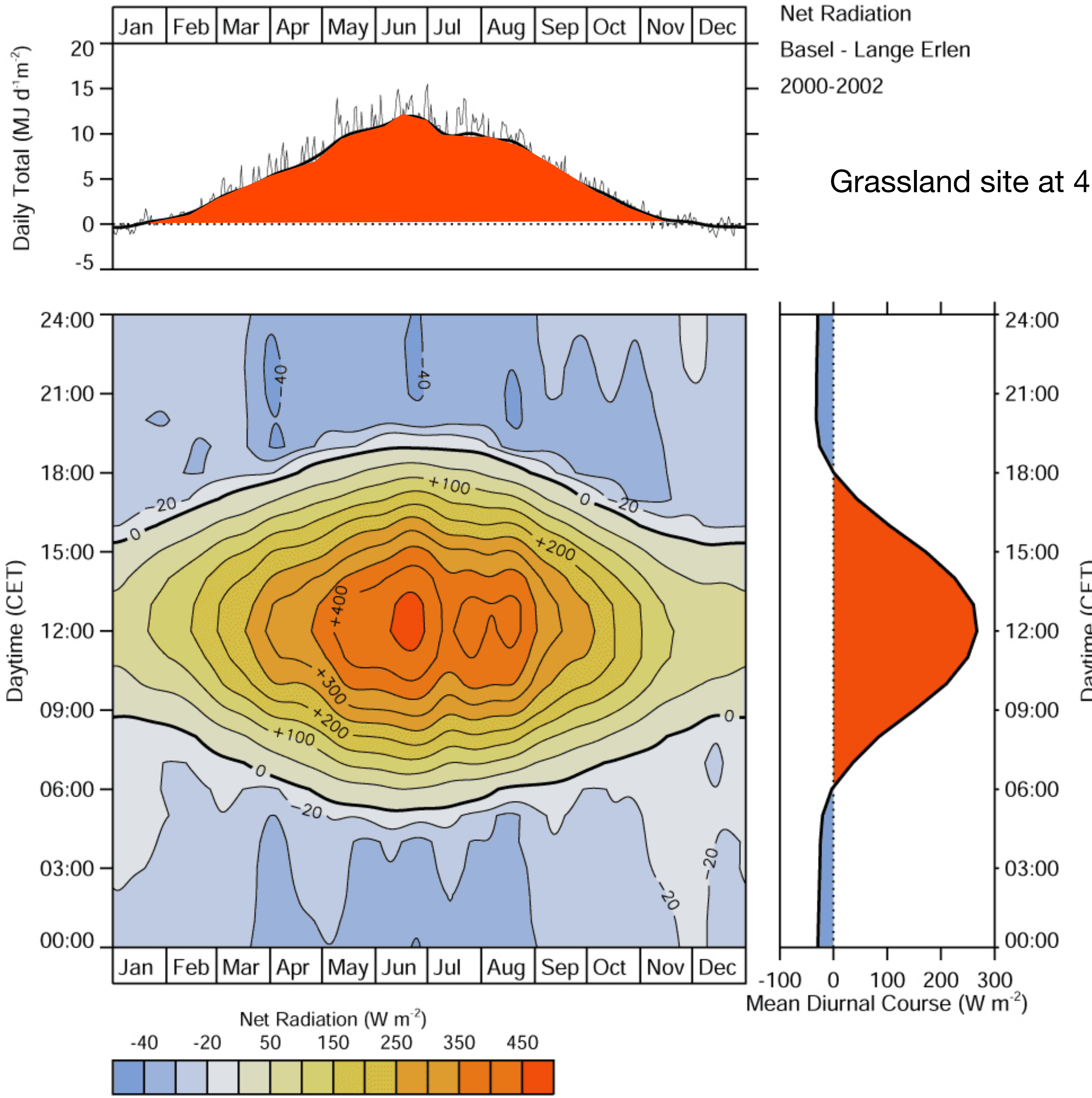
Clouds reduces extremes because they decreases $K{\downarrow}$ and increases $L{\downarrow}$.

Simultaneously measured Q* - different surface properties



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

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



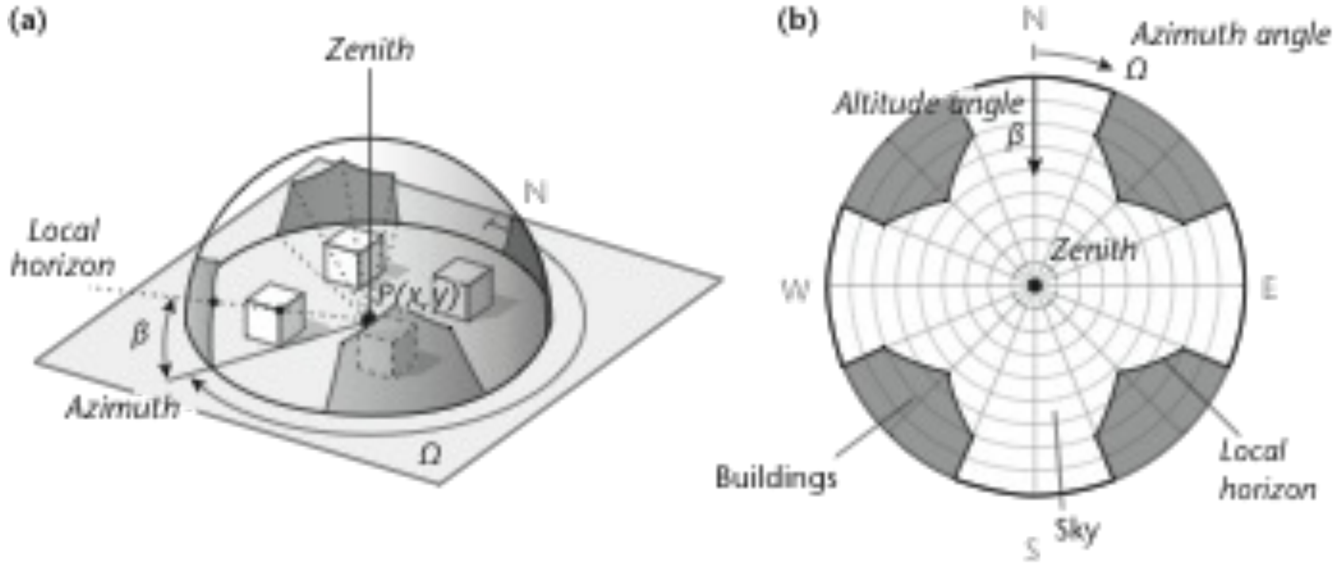
Grassland site at 47° N

R example to make a similar figure (See Assignment 1)

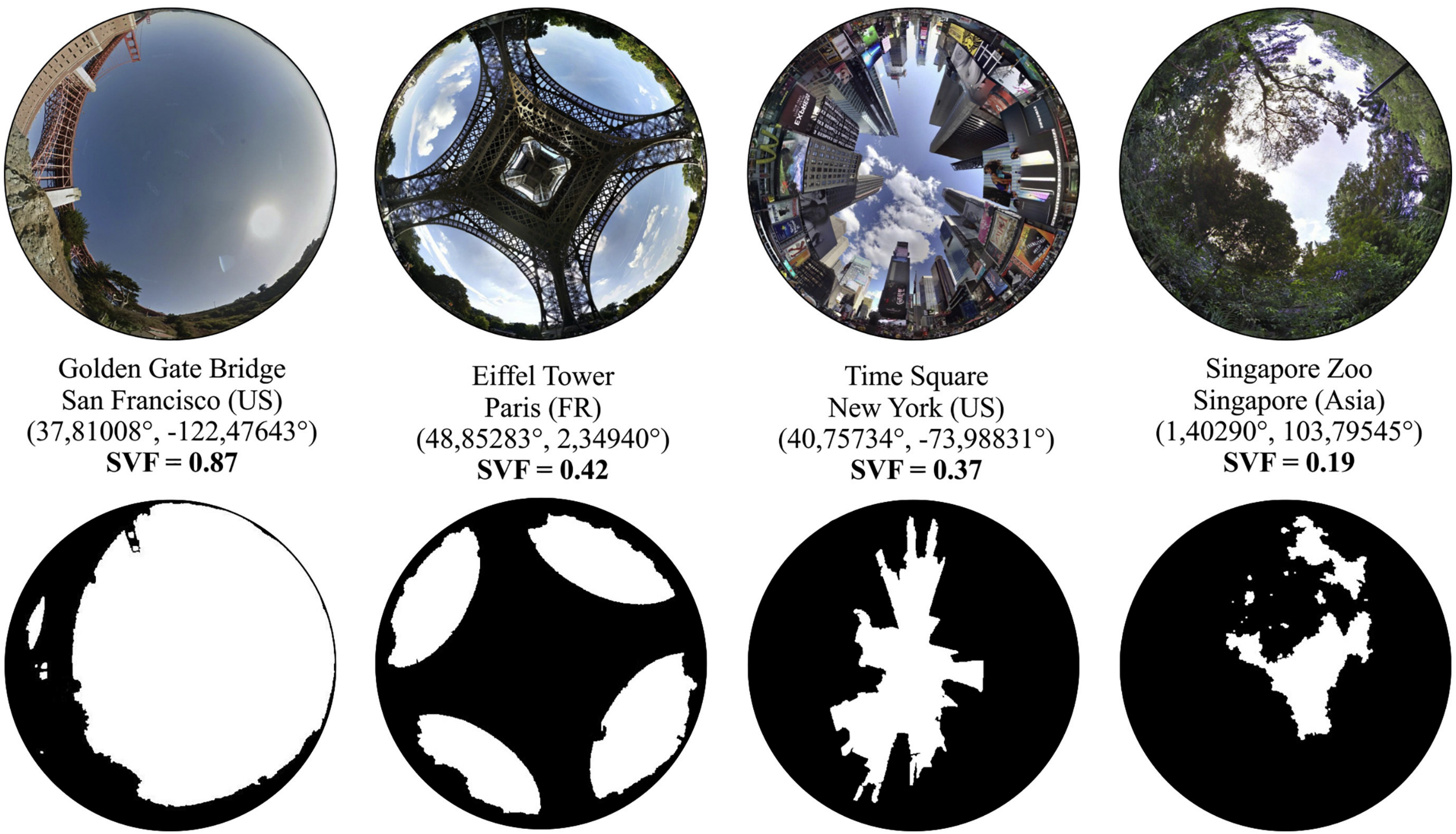
View factors

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:

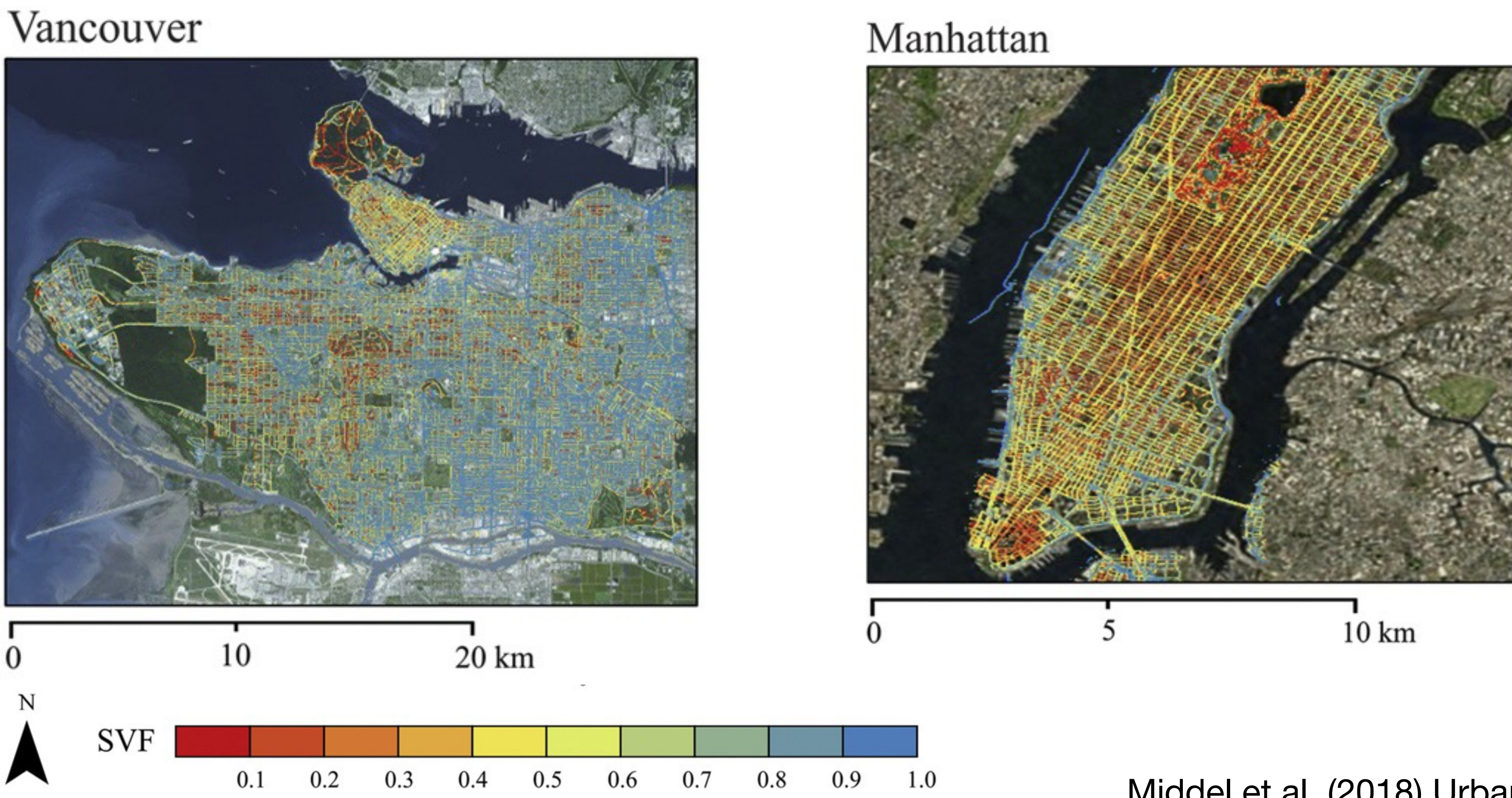


Examples of sky view factors



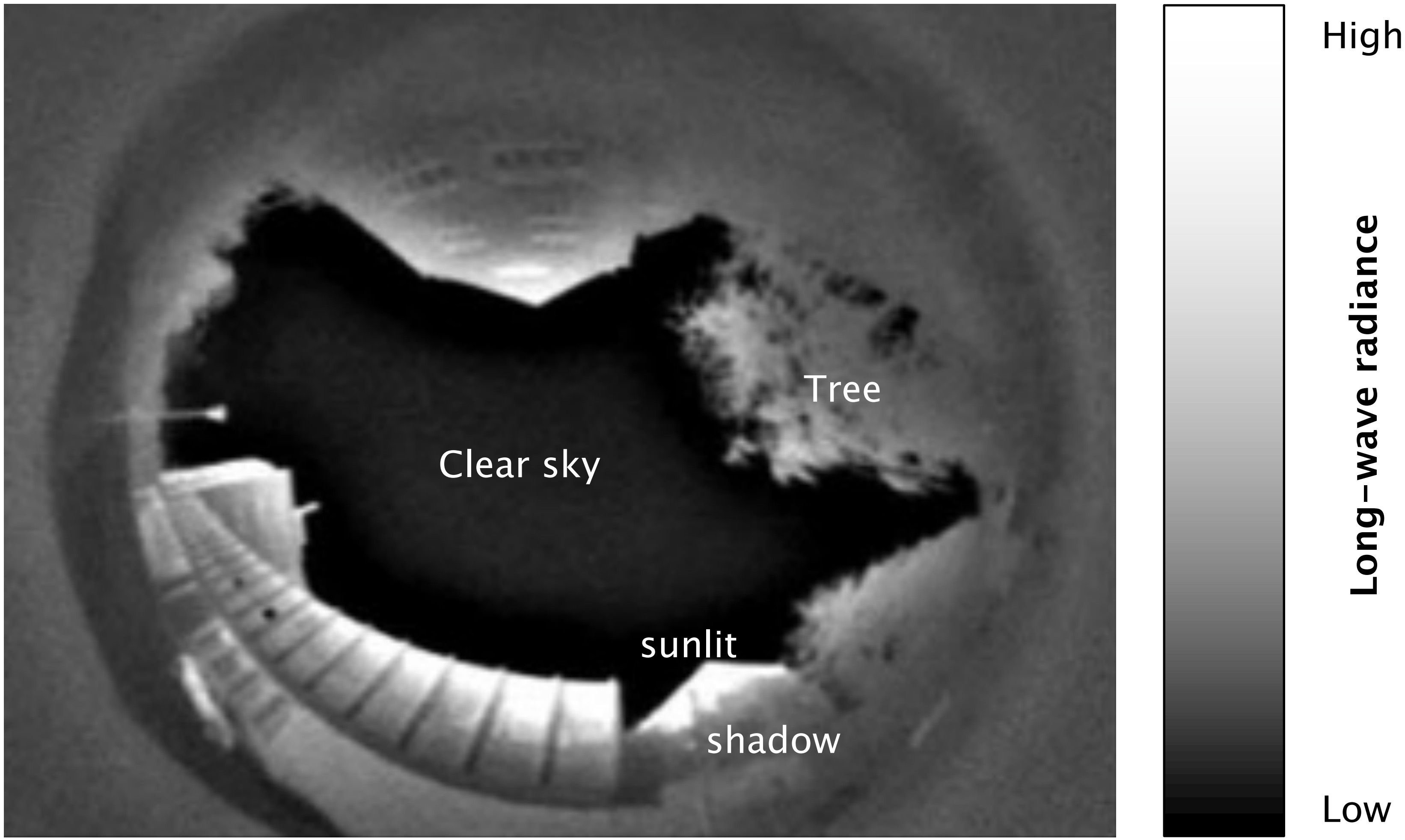
Middel et al. (2018) Urban Climate

Differences across major cities



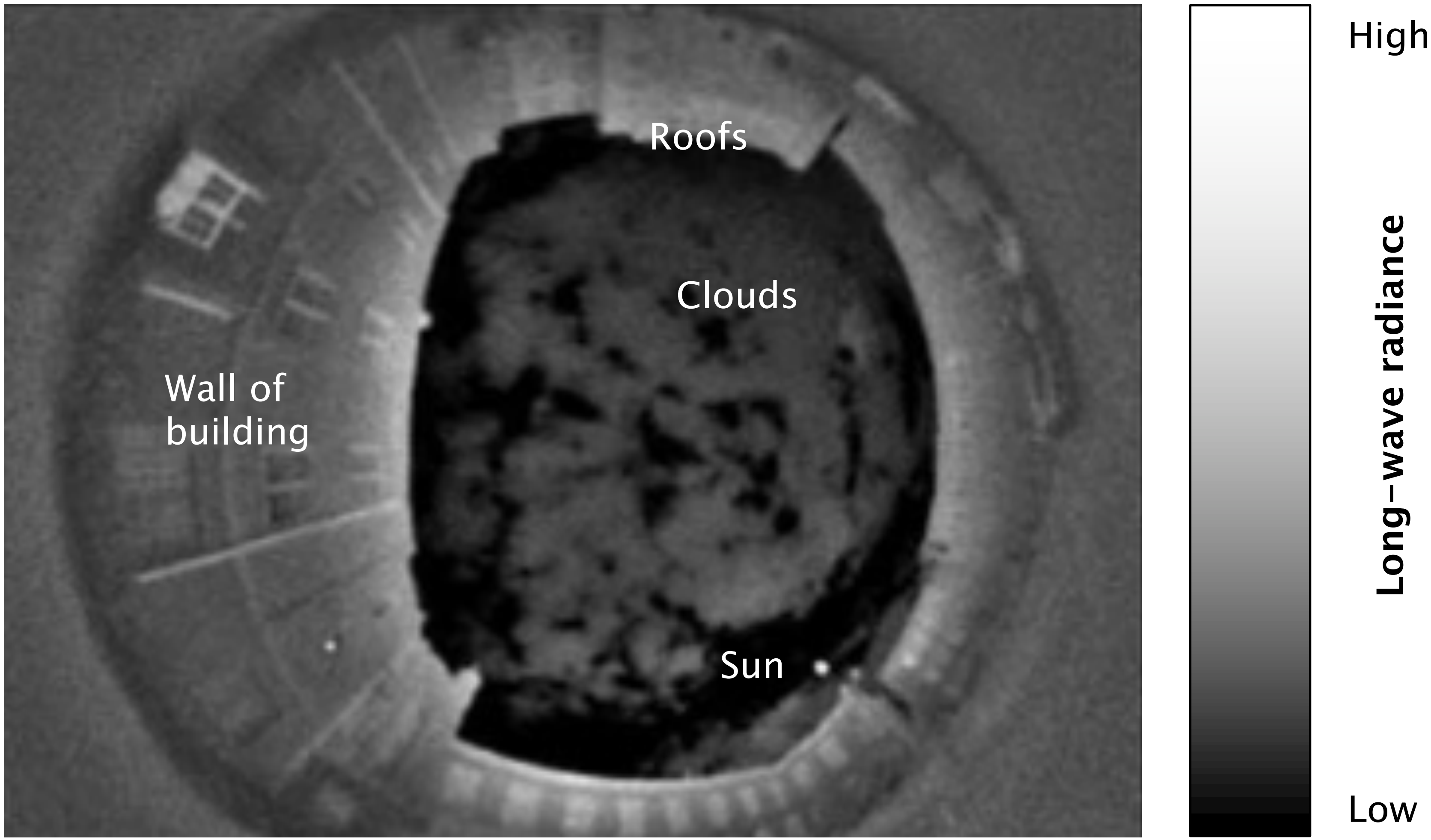
Middel et al. (2018) Urban Climate

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

Thermal infrared through a fish-eye lens



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Geometry control

Photo: A. Christen

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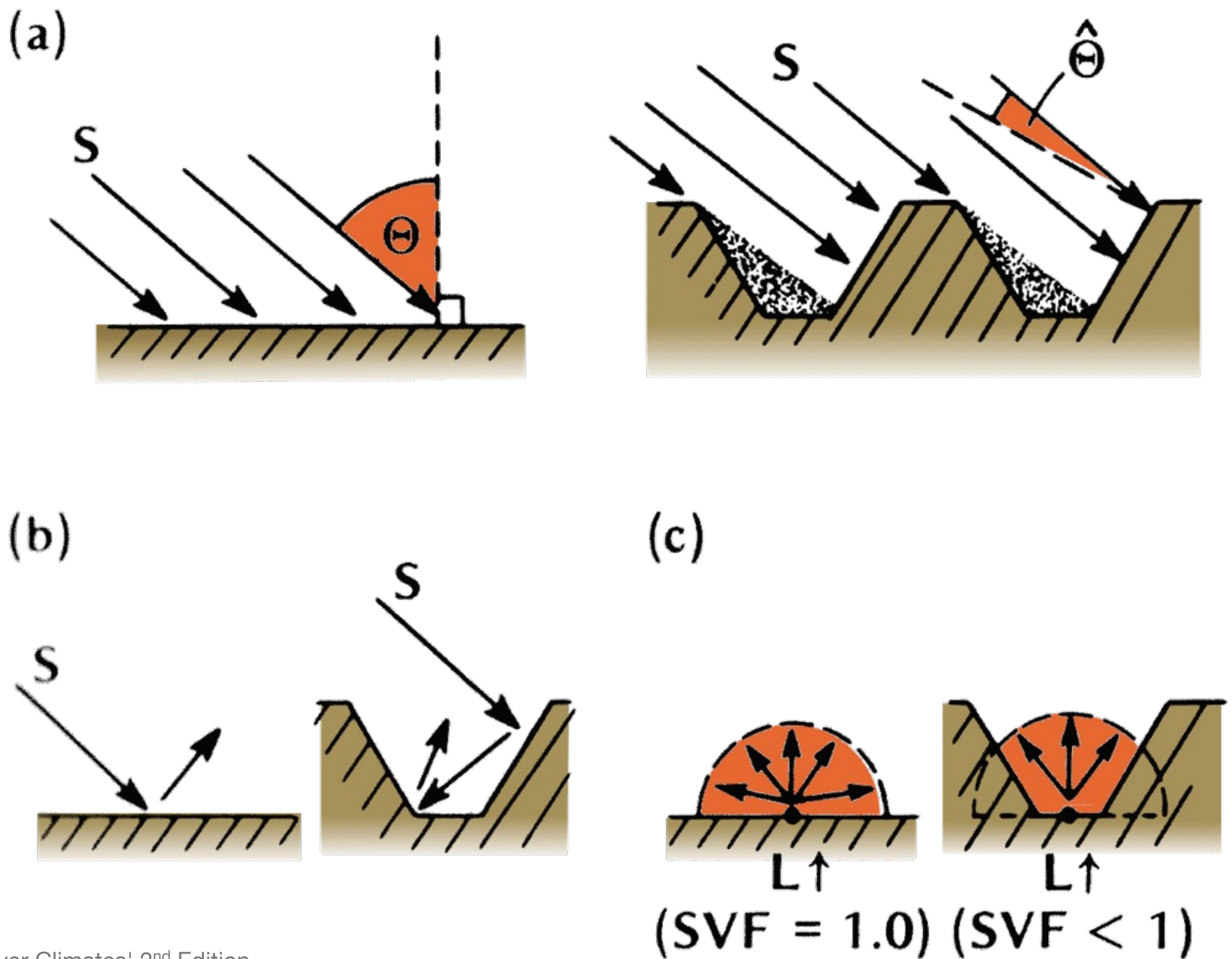
Geometry control of the net all-wave radiation

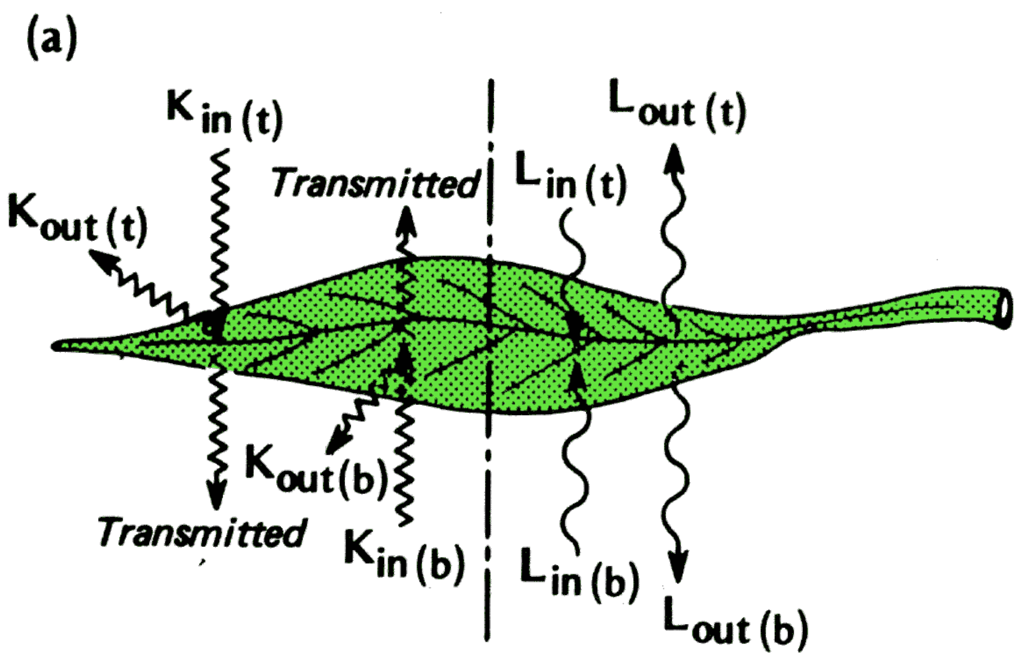


T.R. Oke (1987): 'Boundary Layer Climates' 2nd Edition.


Photo: A. Christen

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:



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

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

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

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

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.