Photo: A. Christen

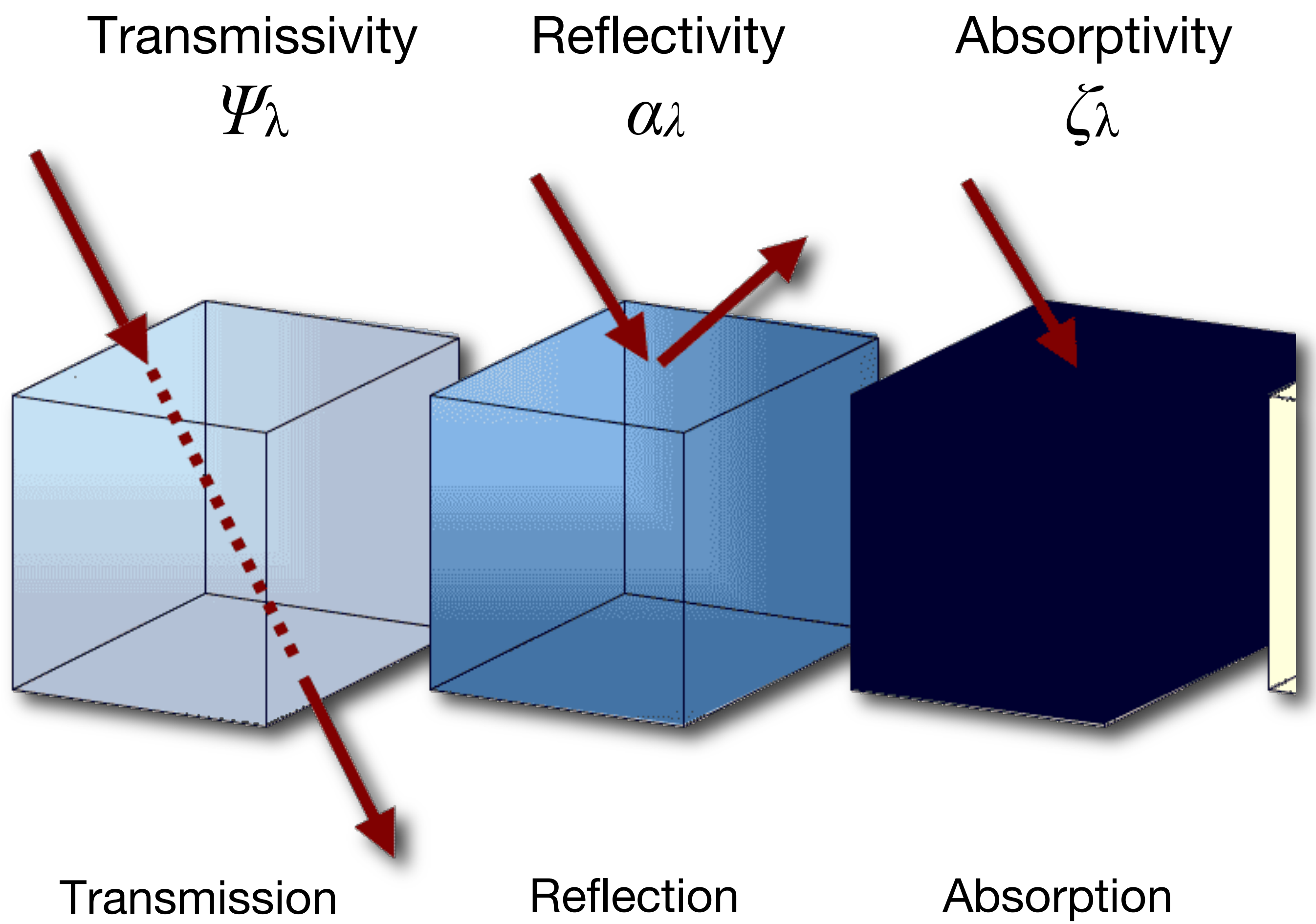
05 Short-wave radiative transfer

Learning objectives

- Describe how radiation interacts with mass.
- Understand how can we determine the transmission of short-wave radiation through the atmosphere.

Photo: A. Christen

Mass-radiation interactions



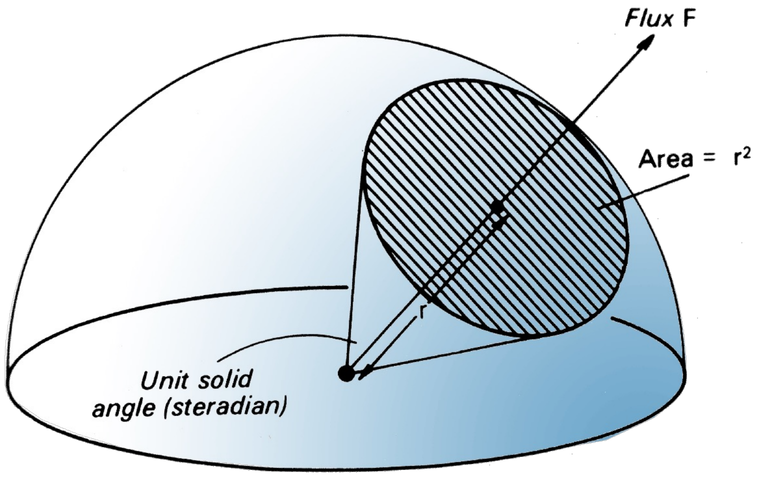
To calculate $K_{\downarrow}$ at the ground, we need to know the effect of the atmosphere in depleting solar radiation.

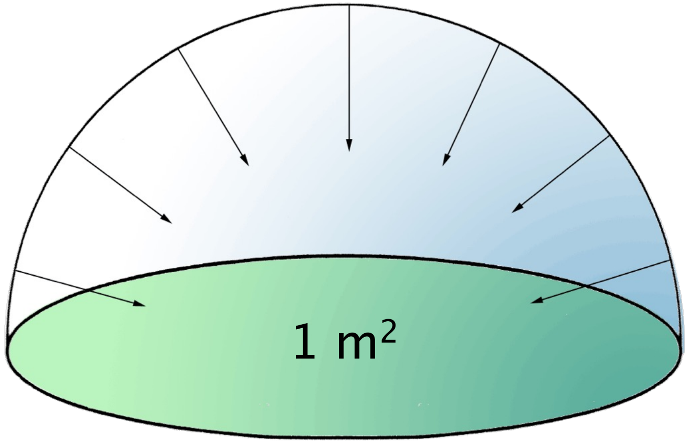
Photo: A. Christen

Definitions

Radiant intensity is the radiation flux per unit solid angle from a point source. The unit of radiant intensity is **W sr^{-1}**

Irradiance Q is the total radiant flux from 2π sr reaching a unit area of a given surface with units **W m^{-2}**.



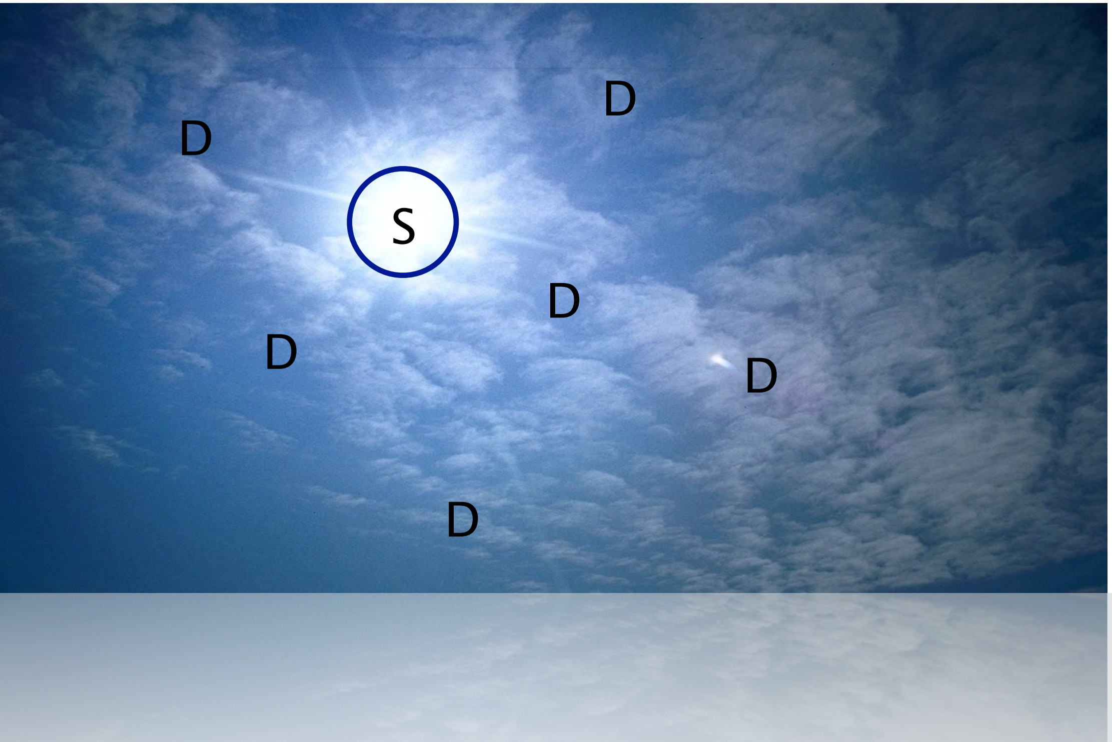


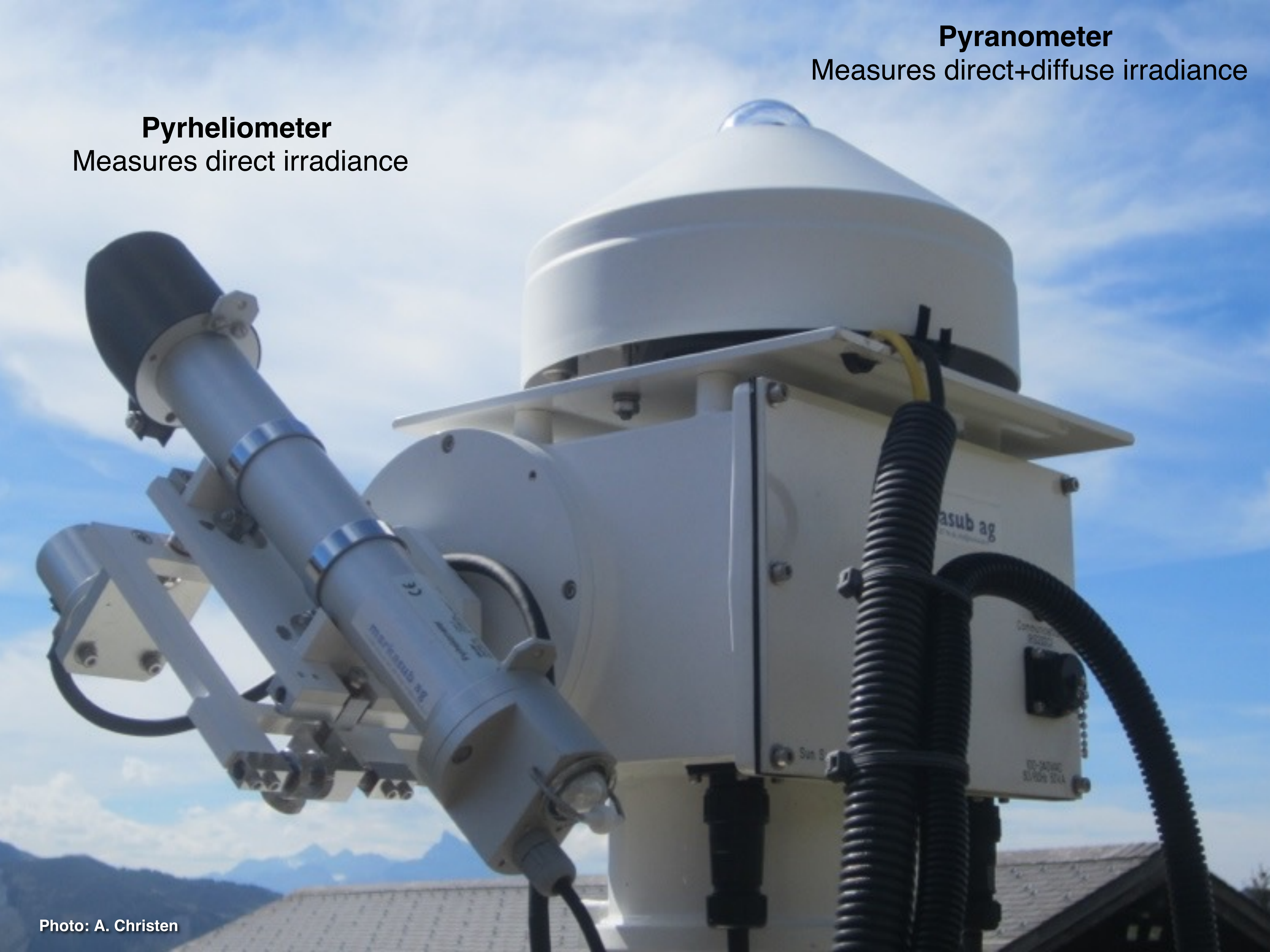
Left figure: T.R. Oke (1987): 'Boundary Layer Climates' 2nd Edition.

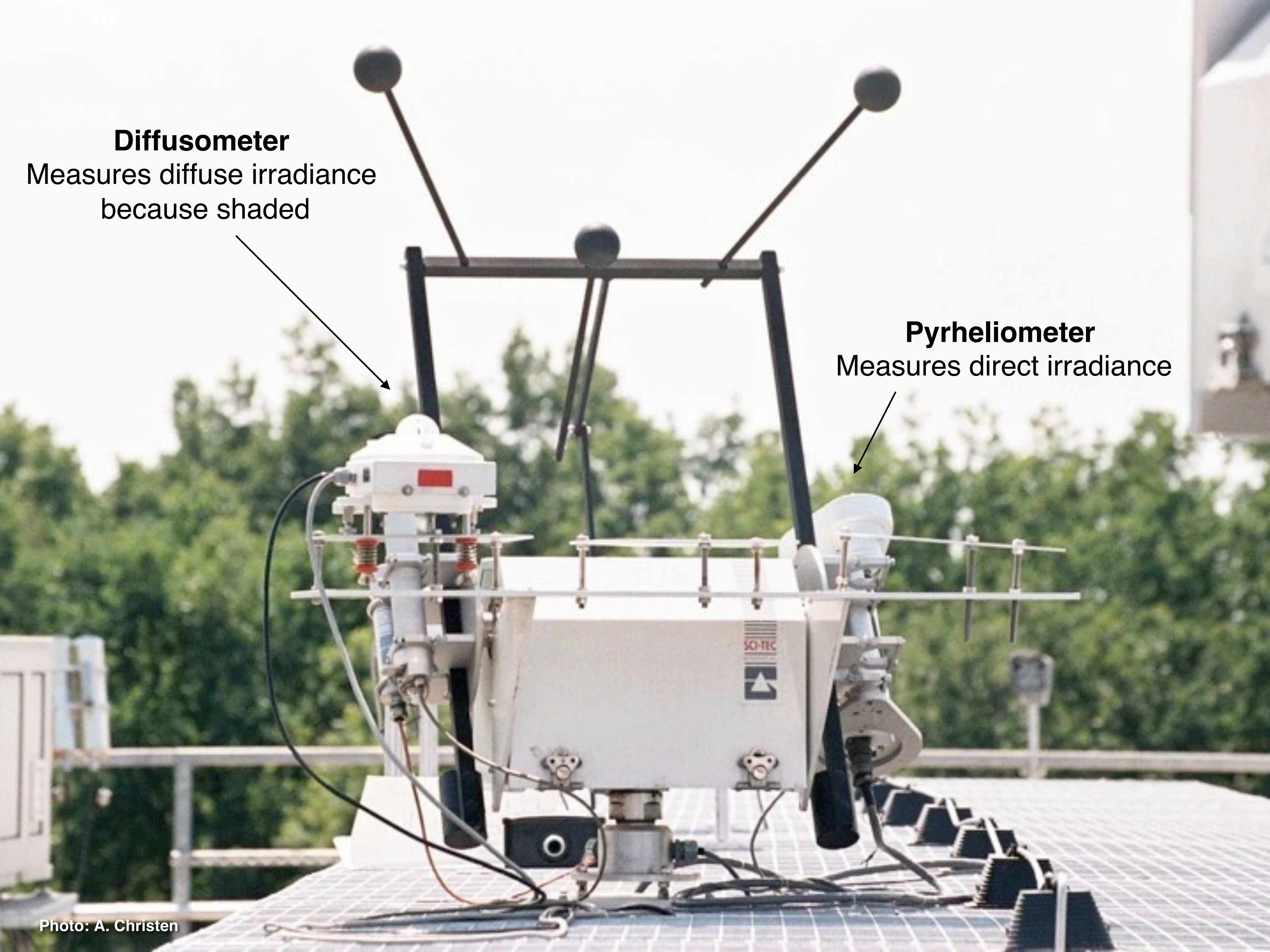
Review: Direct and diffuse irradiance

Two types of solar radiation arrive at the Earth's surface:

- Direct (S): comes directly in parallel rays from Sun.
- Diffuse (D): after scattering and reflection by the Earth's atmosphere and nearby objects.




Pyranometer
Measures direct+diffuse irradiance
Pyrheliometer
Measures direct irradiance
Photo: A. Christen


Diffusometer
Measures diffuse irradiance
because shaded
Pyrheliometer
Measures direct irradiance
Photo: A. Christen

Distribution of direct and diffuse radiation

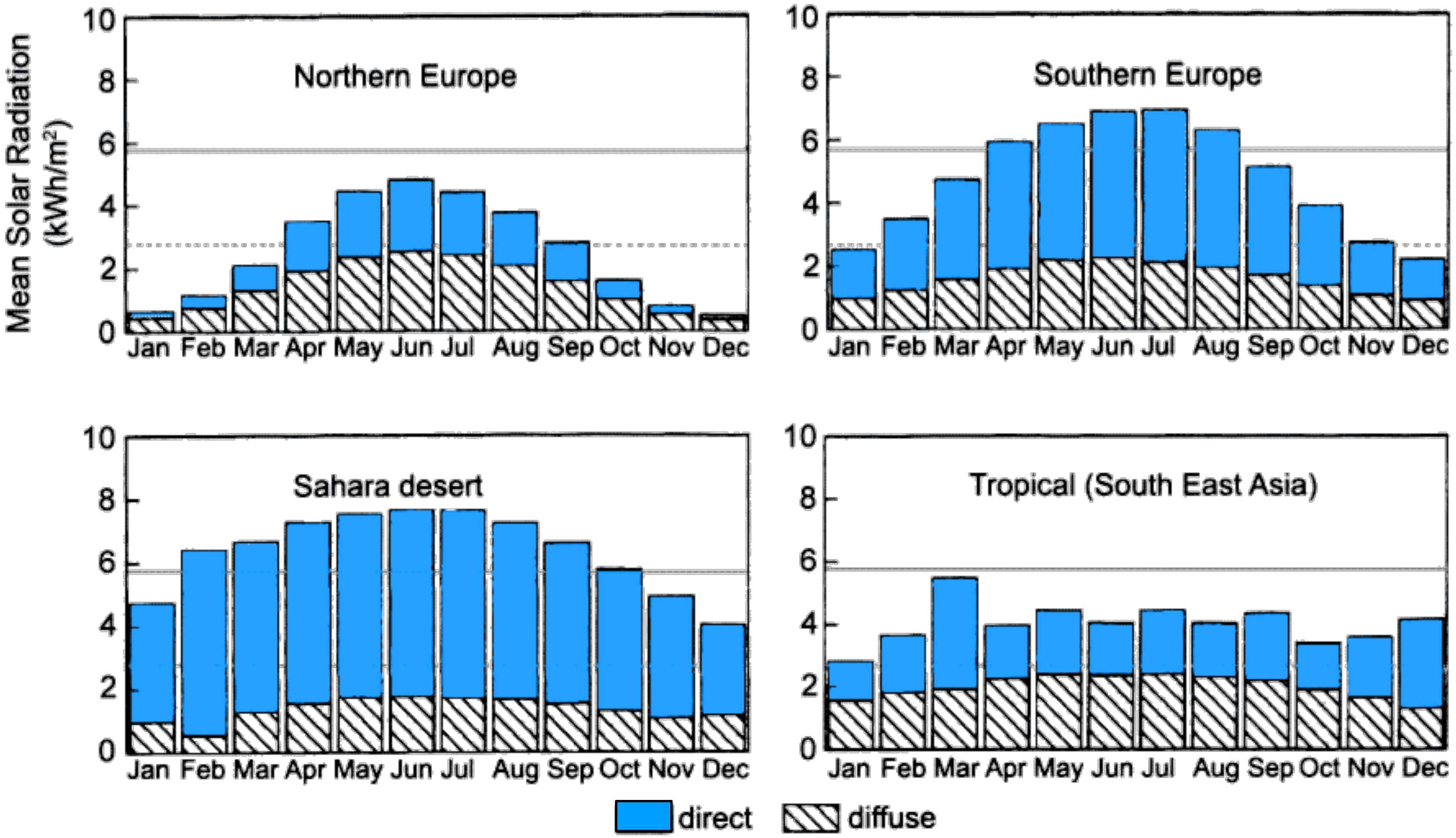



Photo: A. Christen

Calculation of $K_\downarrow$ - slab approach

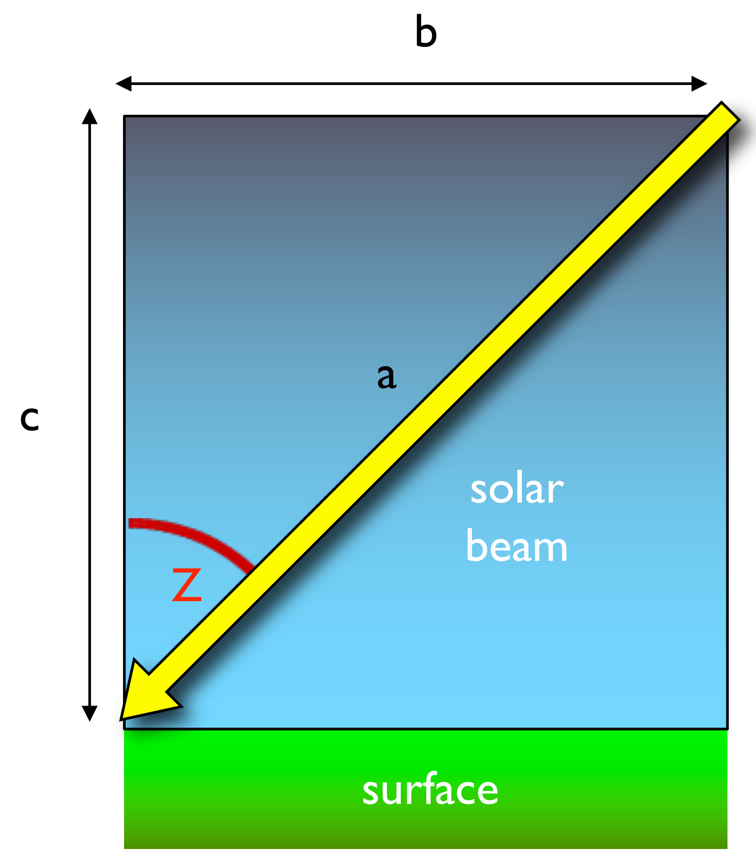
As a simple slab approach we write:

$$K_\downarrow = K_{Ex}\,\Psi_a^m$$

where the vertical transmissivity of the atmosphere Ψ_a depends on turbidity of the air (scattering + absorption) and path length trough the atmosphere (m, the optical air mass number).

$$m = \frac{\text{slant path}}{\text{zenith distance}} = \frac{a}{c} = \cos Z^{-1}$$

Ψ_a varies from about 0.9 (clean) to 0.6 (dirty, smog)



Test your knowledge (Slido)

Assuming that KEx is 450 W m^{-2}, $\Psi_a = 0.84$, and Z = 68°, what is K↓?

$$K_{\downarrow} = K_{Ex}\,\Psi_a^m$$

$$m = \cos Z^{-1}$$

$\Psi_a = 0.80$

$\Psi_a = 0.73$


www.katcam.ca
$\Psi_a = 0.58$
05-Aug-2010 (forest fires)


A. Christen


A. Christen
A. Christen

Physically based calculation of $K_{\downarrow}$

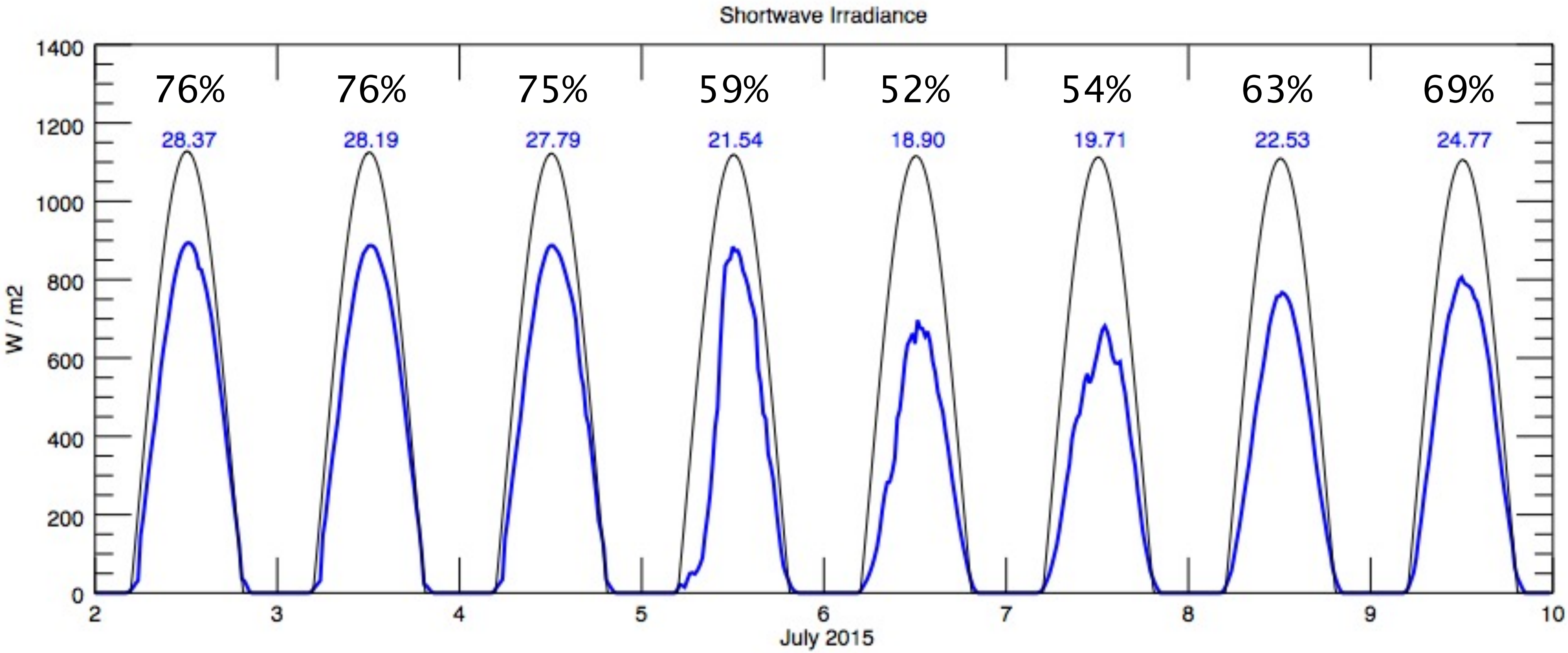
Essentially these models attempt (with varying degrees of completeness) to account for all physical processes in the chain:

I_0 ➔ K_{Ex} ➔ $K_{\downarrow}$ cloudless, horiz. surface ➔ $K_{\downarrow}$ cloudy, horiz. surface ➔ $K_{\downarrow}$ sloping terrain

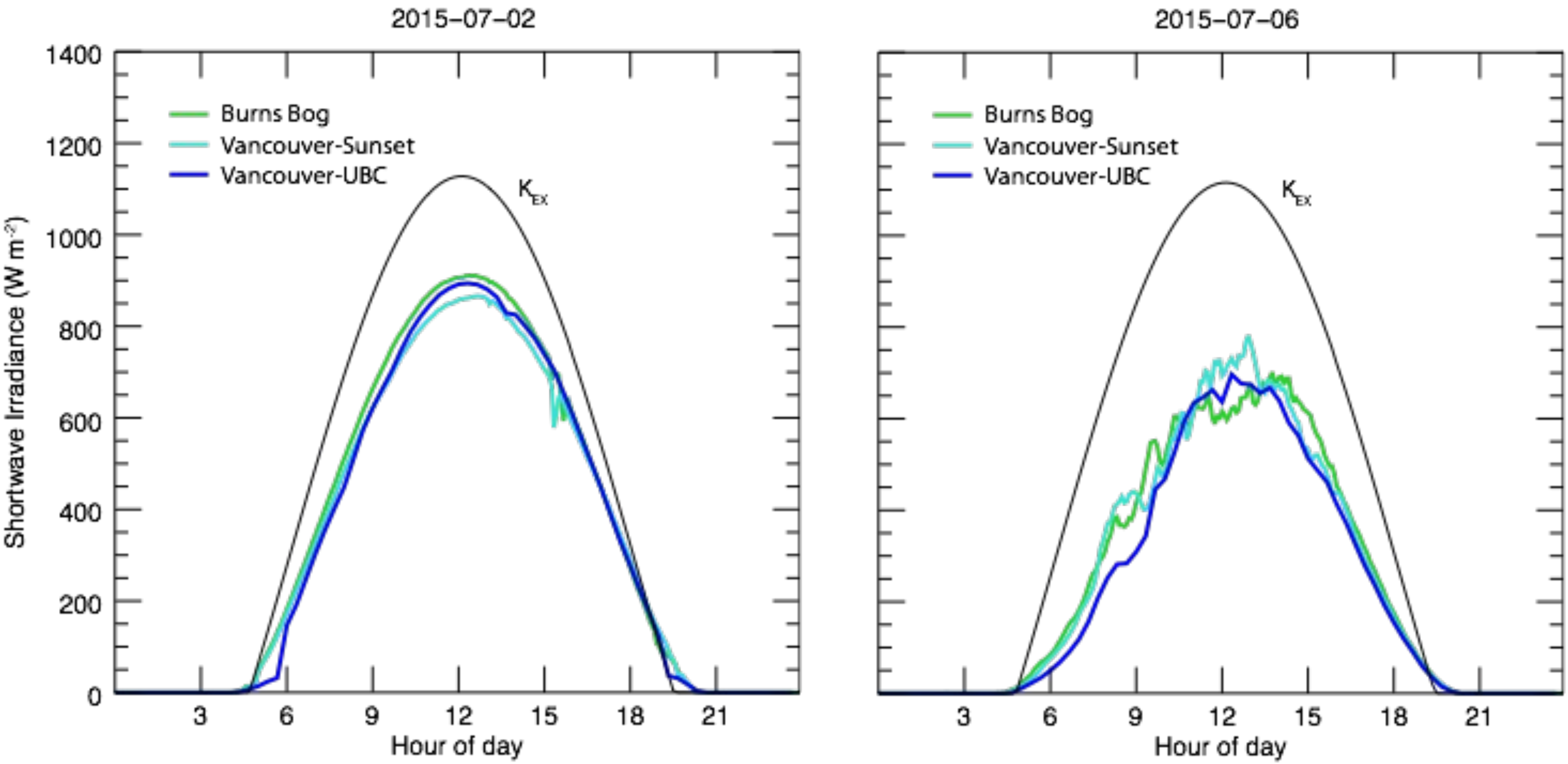
Examples of physically based models:

- Won (1977): Using meteorological data / accounts for clouds.
- Davies et al. (1975): Treats S and D separately / accounts for clouds.
- LOWTRAN (1972, Low Resolution Transmittance Code, Air Force Cambridge Research Laboratory, free)
- MODTRAN (1989, Moderate Resolution Transmittance Code, Air Force Research Laboratory, needs a Software license)

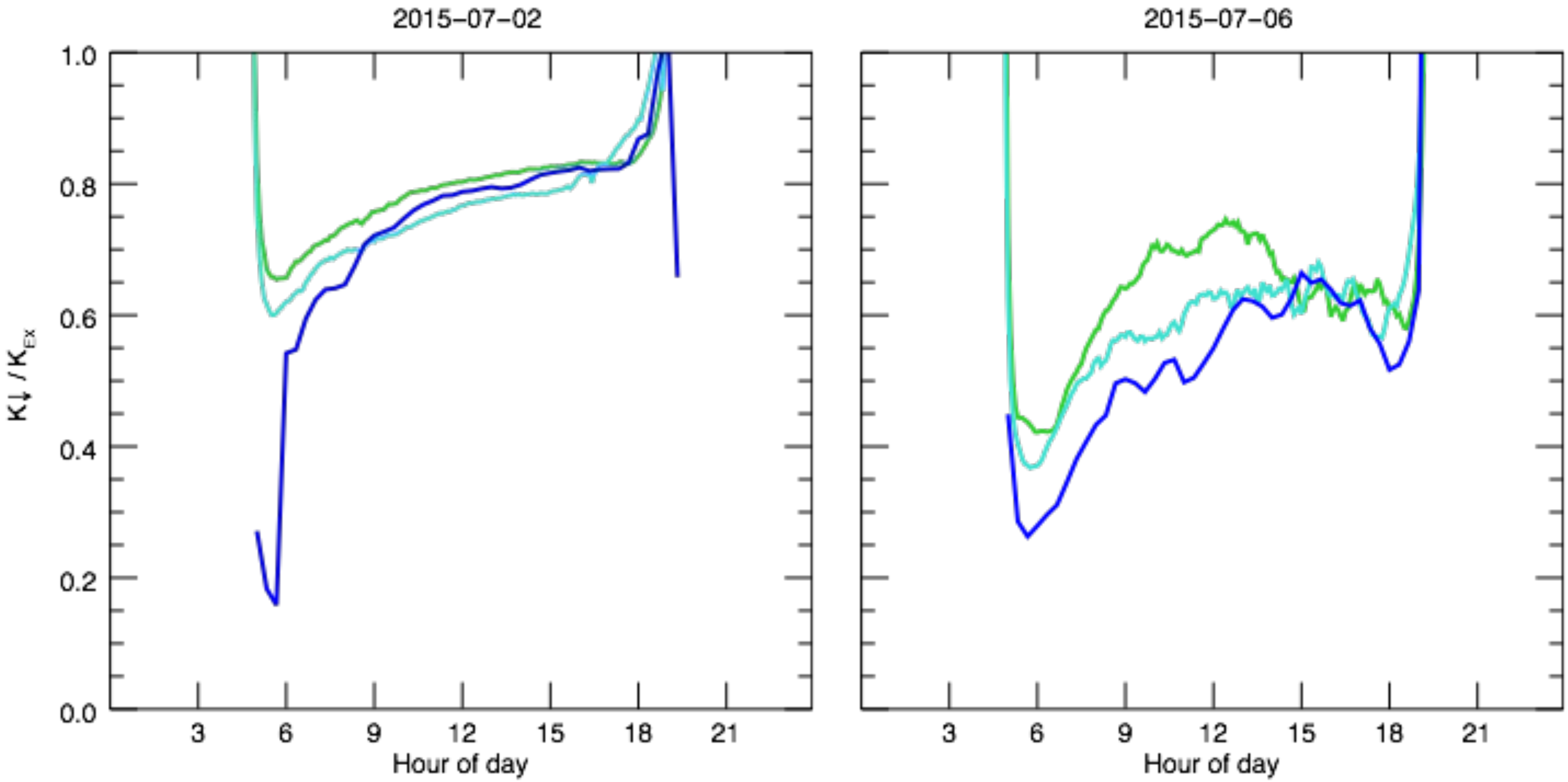
July 2 to 9, 2015



Effect of forest fire smoke



Summer 2015 - effect of forest fire smoke



Take home points

- As short-wave radiation passes through the atmosphere, it is **reflected, scattered** and **absorbed**.
- At the surface, we therefore experience **diffuse irradiance** in addition direct-beam irradiance.
- The transmission of direct-beam radiation can be described by a slab approach using a **bulk atmospheric transmissivity**.