Photo: J. Verfaillie

06 Short-wave reflection and albedo

Learning objectives

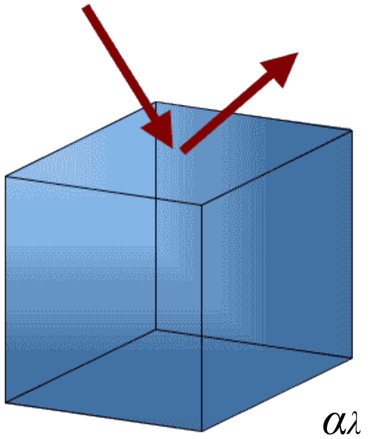
- Describe how we can quantify and model the short-wave spectral properties of a surface.
- Explain how a surface's reflectivity is affected by surface geometry.
- Understand how the sun's position relative to an object affects reflectivity.

Photo: S. Knox

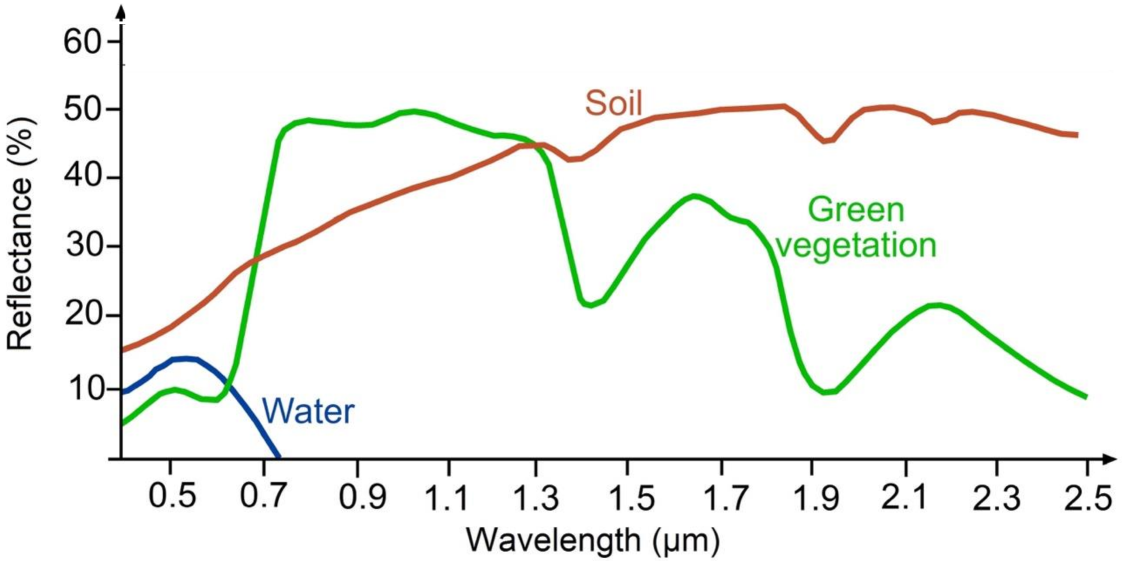
Reflectivity and reflection coefficient

Spectral reflectivity

$$\alpha_\lambda = \frac{\text{radiation reflected}}{\text{radiation incident}}$$ ★



Spectral reflectivity α_λ relates to a **single** wavelength.



Source: http://www.seos-project.eu/modules/classification/classification-c01-p05.html

Reflectivity and reflection coefficient

Spectral reflectivity

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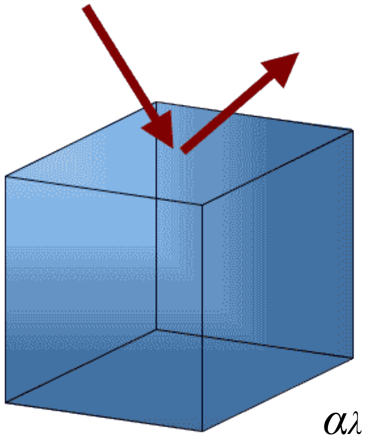
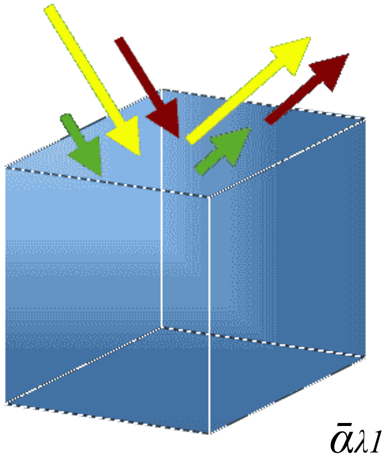


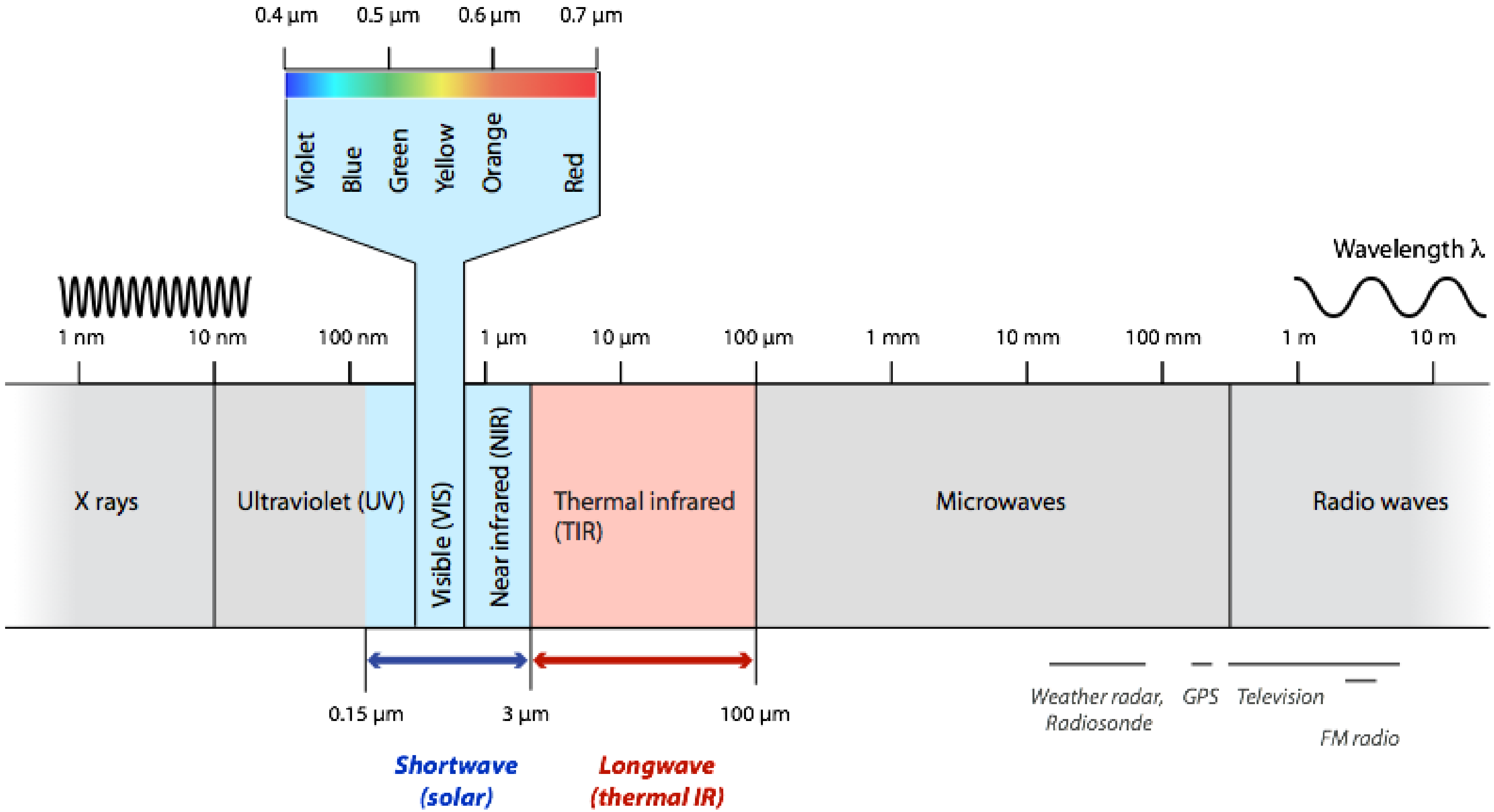
Reflection coefficient – Average reflectivity from $\lambda_1 \rightarrow \lambda_2$ weighted by distribution of incoming radiation in the same waveband:

$$\bar{\alpha}_{\lambda_1 \rightarrow \lambda_2} = \frac{\int_{\lambda_1}^{\lambda_2} \alpha_\lambda I_\lambda d\lambda}{\int_{\lambda_1}^{\lambda_2} I_\lambda d\lambda}$$

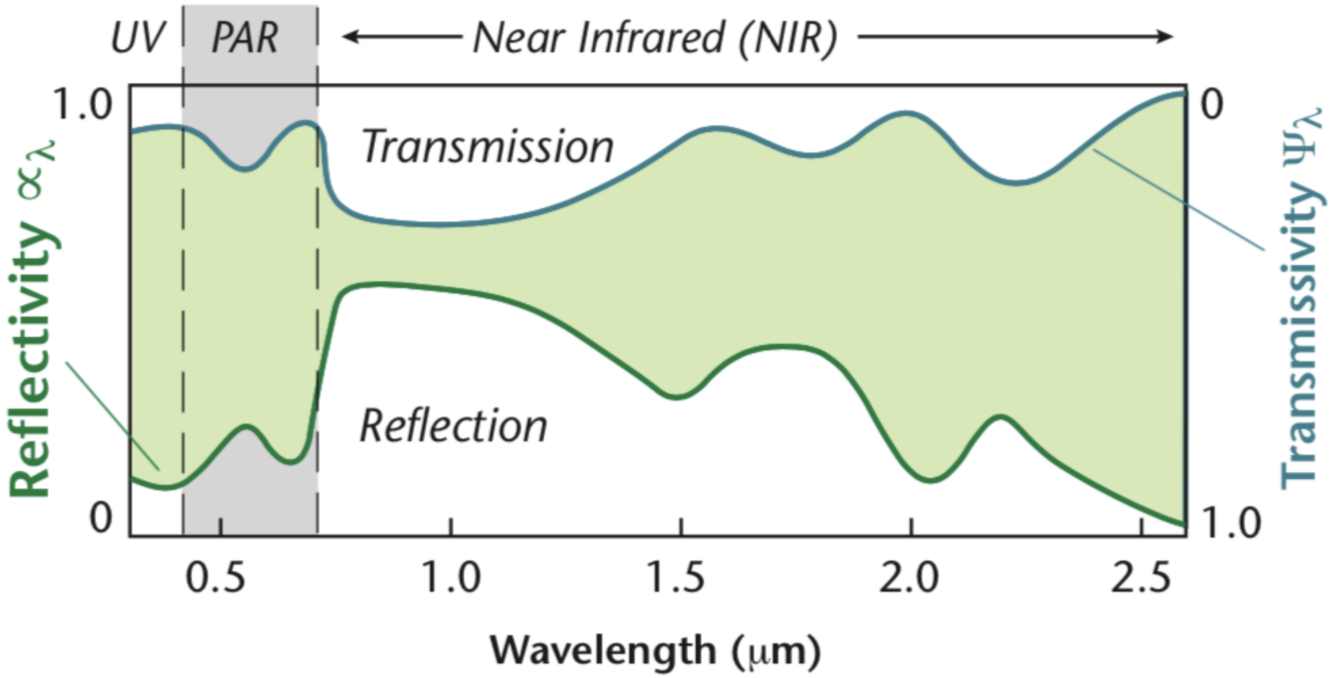
when $\lambda_1 \rightarrow \lambda_2$ refers to the whole solar band (0.15 to 3 µm) $\bar{\alpha}_{\lambda_1 \rightarrow \lambda_2} = \bar{\alpha}_\lambda$ is called **surface albedo** α.



The electromagnetic spectrum

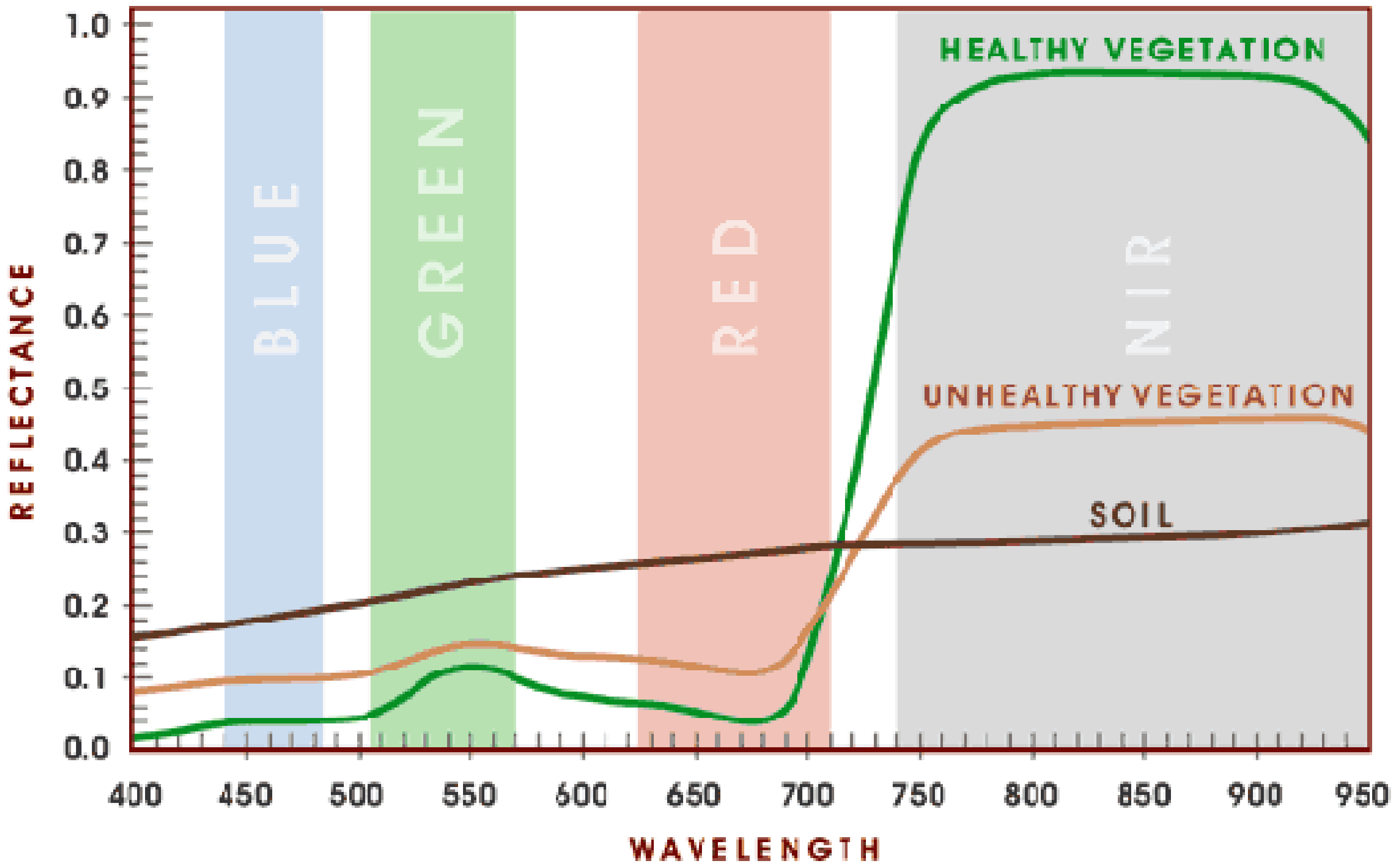


Spectral reflectivity of a leaf



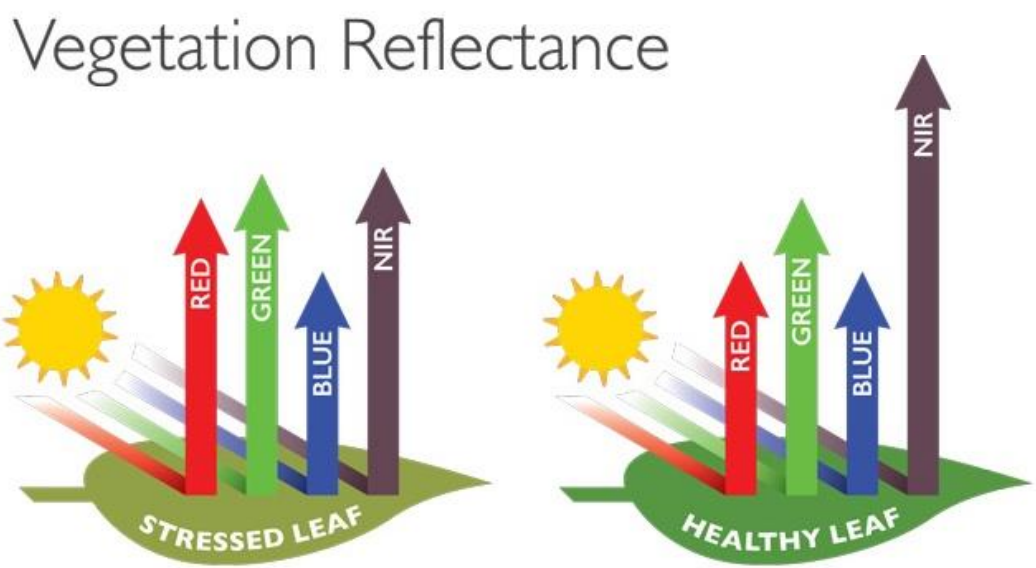
What does the green area represent?

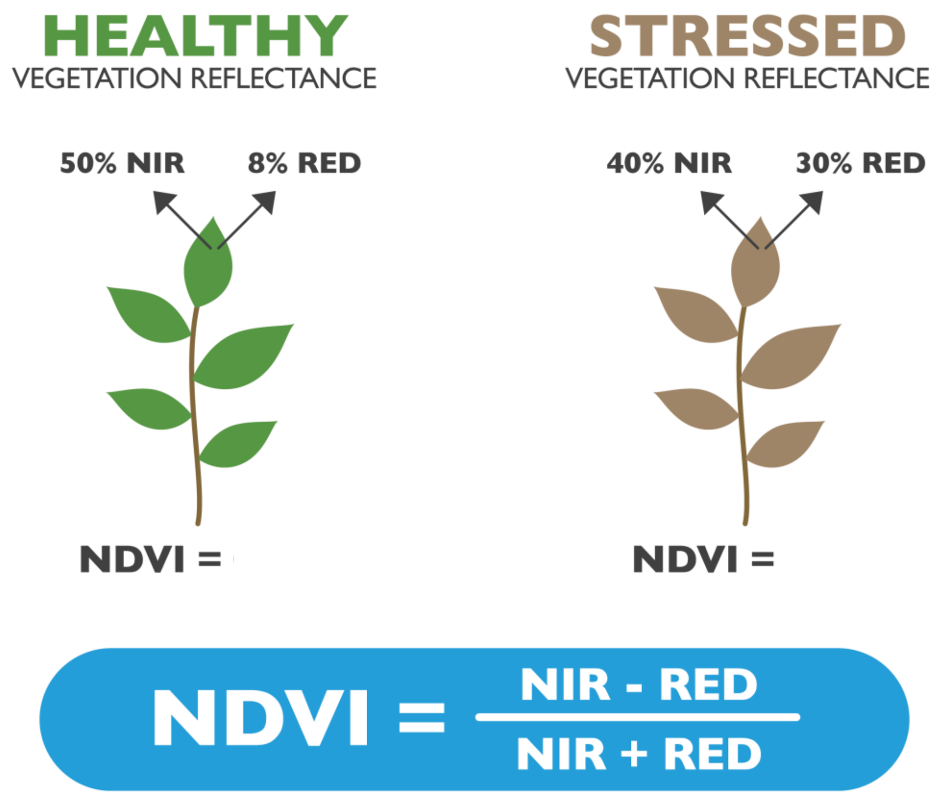
Spectral reflectivity of healthy vs. unhealthy vegetation



Source: http://physicsopenlab.org/2017/01/30/ndvi-index/

Measuring vegetation health - normalized difference vegetation index



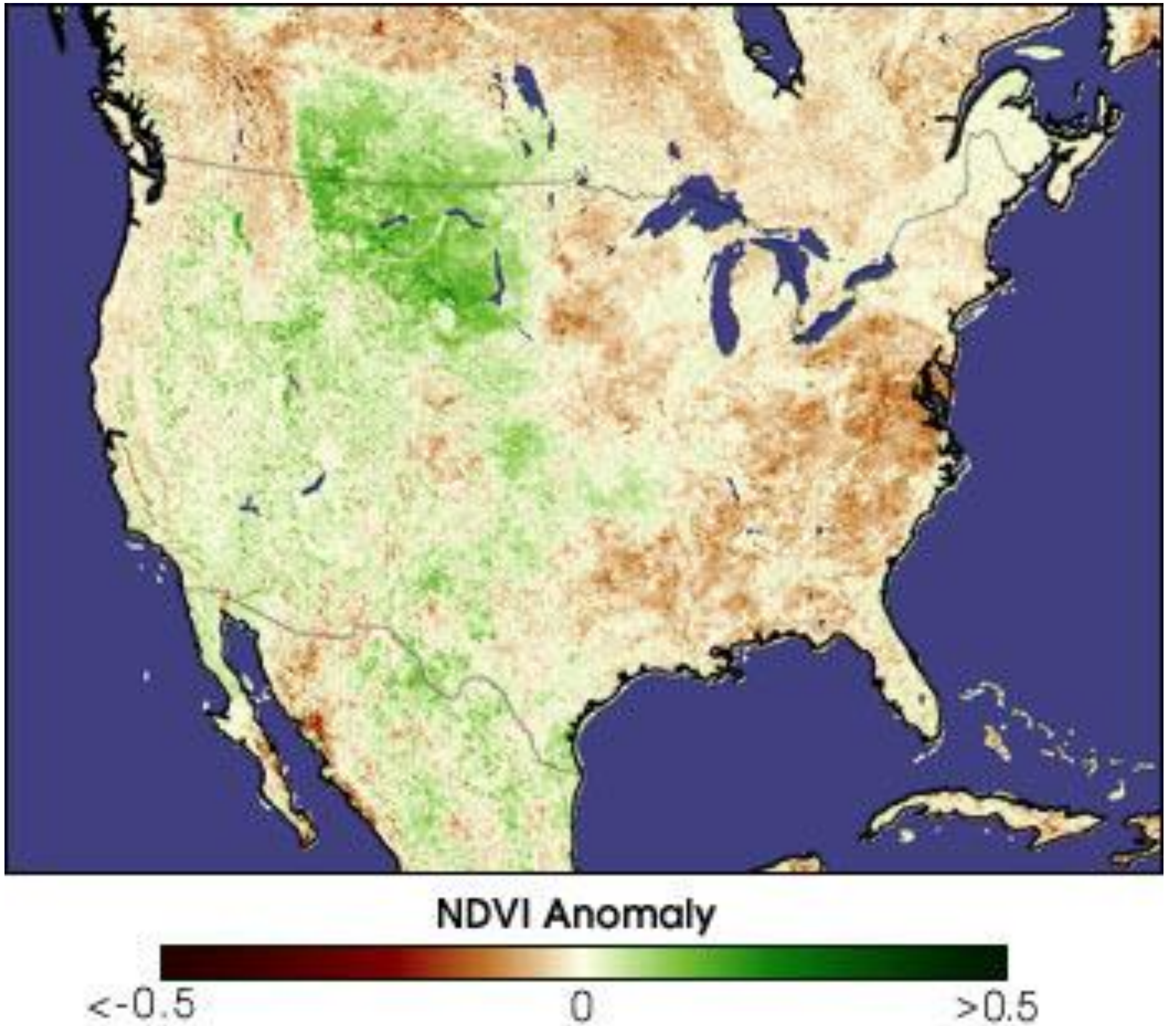


Source: https://www.agricolus.com/en/indici-vegetazione-ndvi-ndmi-istruzioni-luso/

NDVI at the global scale

Source: https://svs.gsfc.nasa.gov/3584

NDVI as an indicator of drought

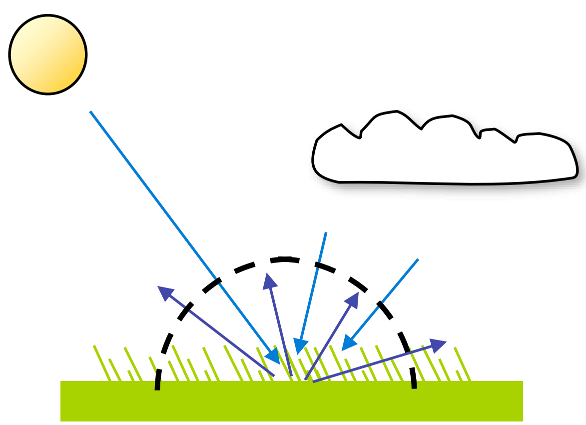


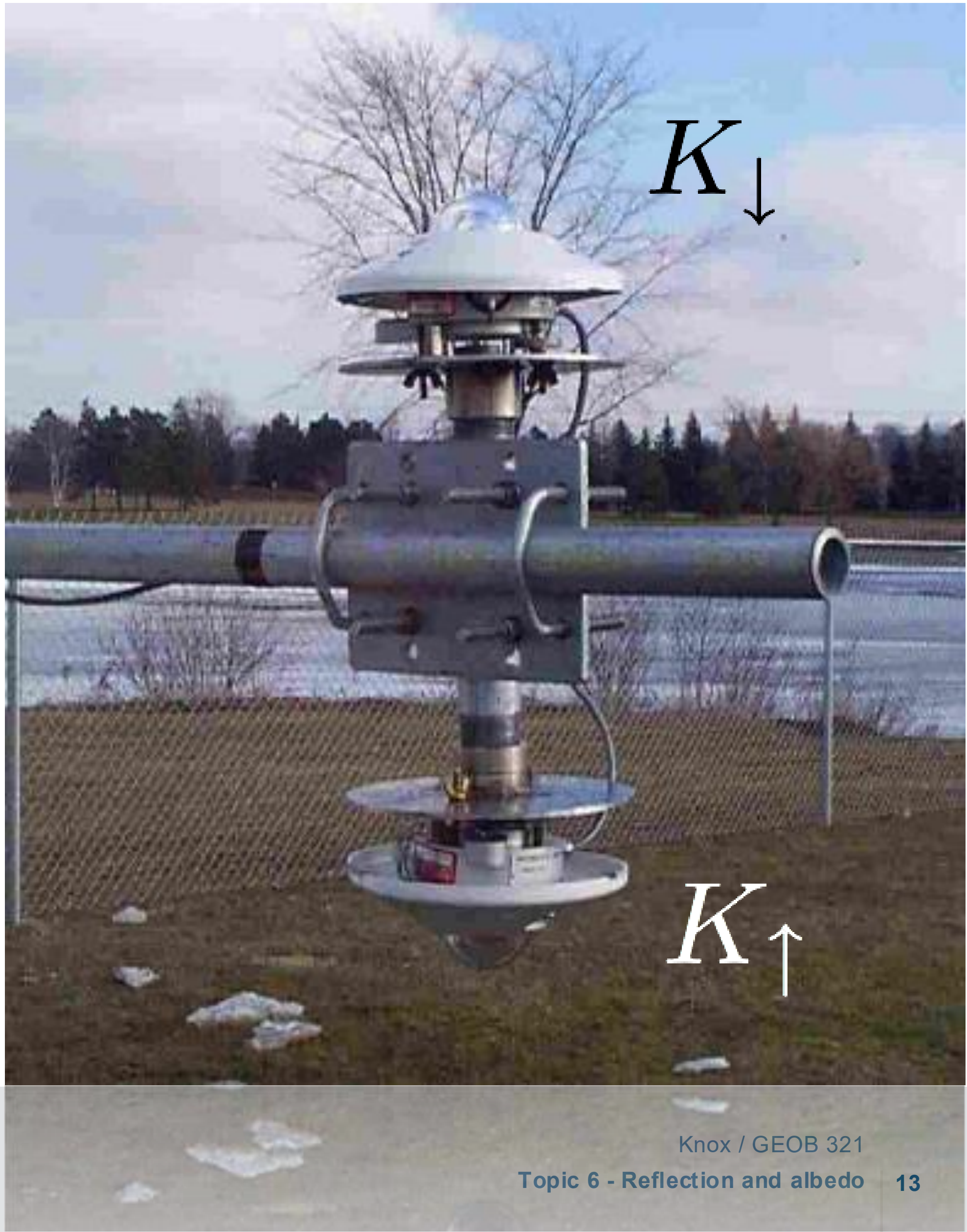
Source:
https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_3.php

Review: Albedo

The albedo α can be simply measured as the fraction of incident solar radiation reflected by a surface.

$$\alpha = \frac{K_{\uparrow}}{K_{\downarrow}} \quad \star$$





Albedo

Albedo is a very significant surface variable to microclimate because it controls the absorption of the main source of energy by day.

Albedo has a strong influence on the climate system. Adjacent surfaces receive the same amount of K↓ but the impact is determined by α.

Surface	α
Fresh snow	
Old snow	
Short grass	
Crops	
Deciduous Forests	
Coniferous Forests	
Water *	

Shown are typical values. Individual values vary widely.
* for small zenith angles Z only.

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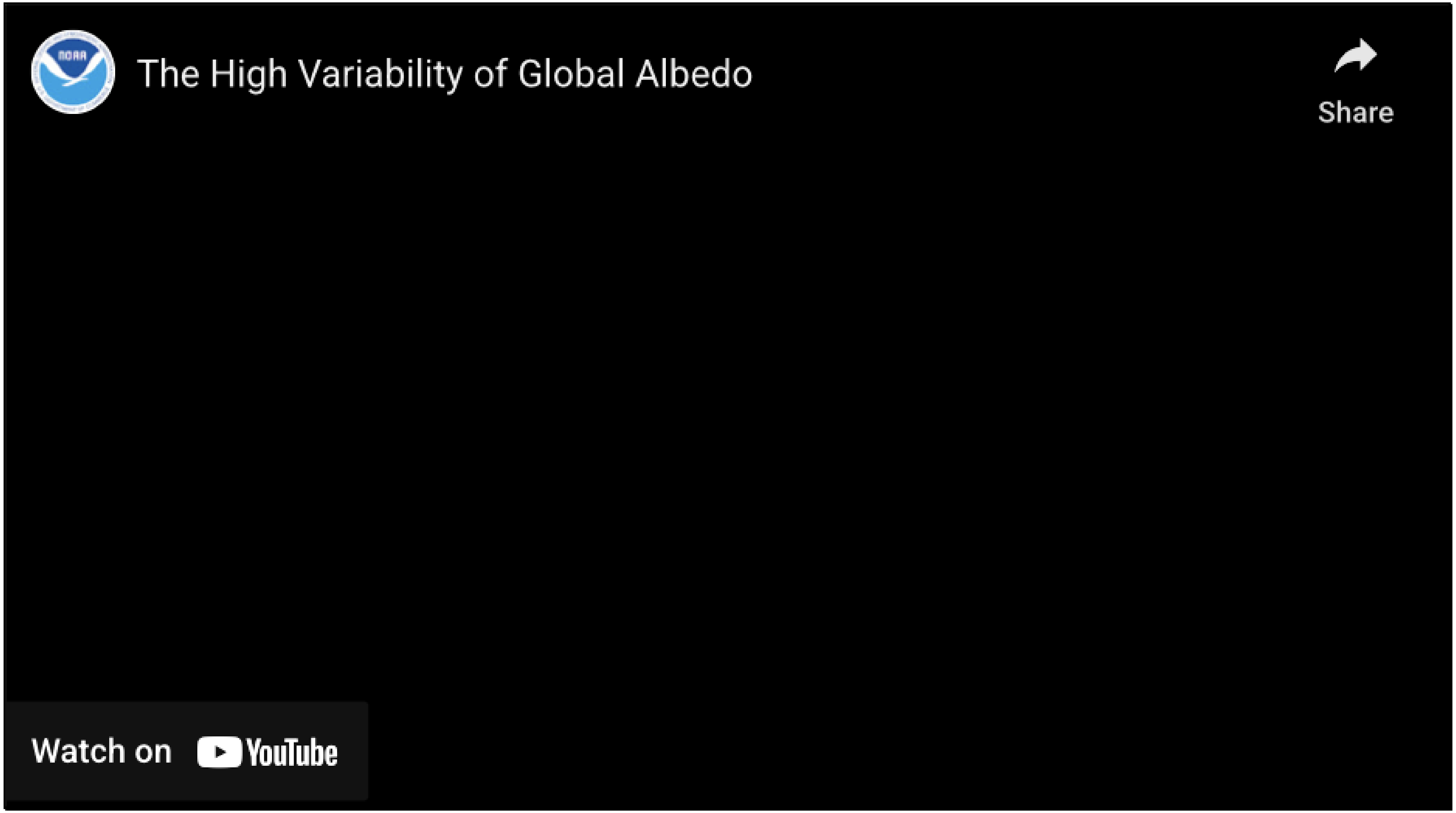
Surface	α
Fresh snow	0.95
Old snow	0.4
Short grass	0.25
Crops	0.2
Deciduous Forests	0.2
Coniferous Forests	0.1
Water *	0.05

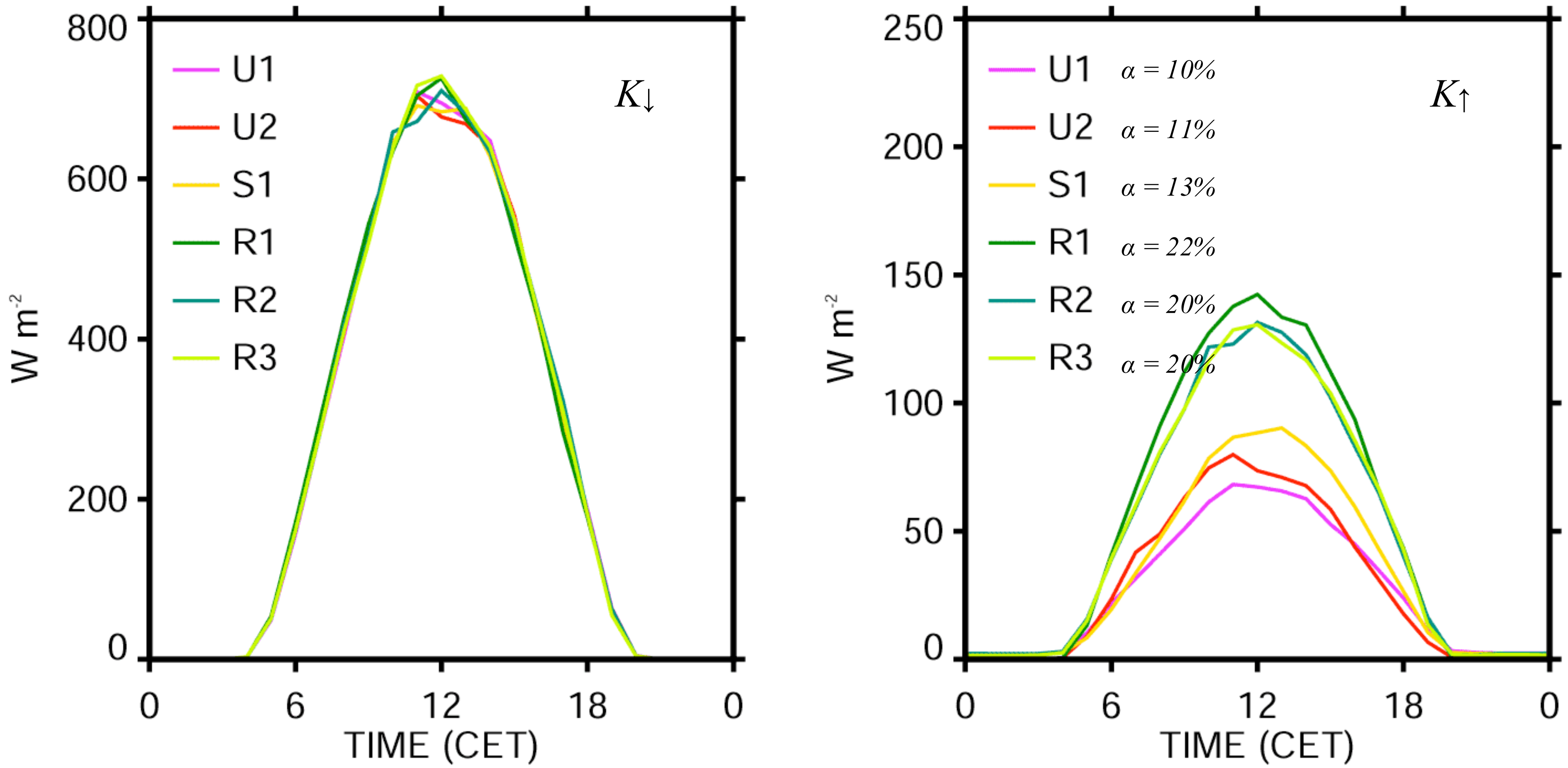
Shown are typical values. Individual values vary widely.
* for small zenith angles Z only.

Albedo - globally



Source: https://www.youtube.com/watch?v=O0B8Yi7AZvQ

Shortwave reflection creates energetic differences

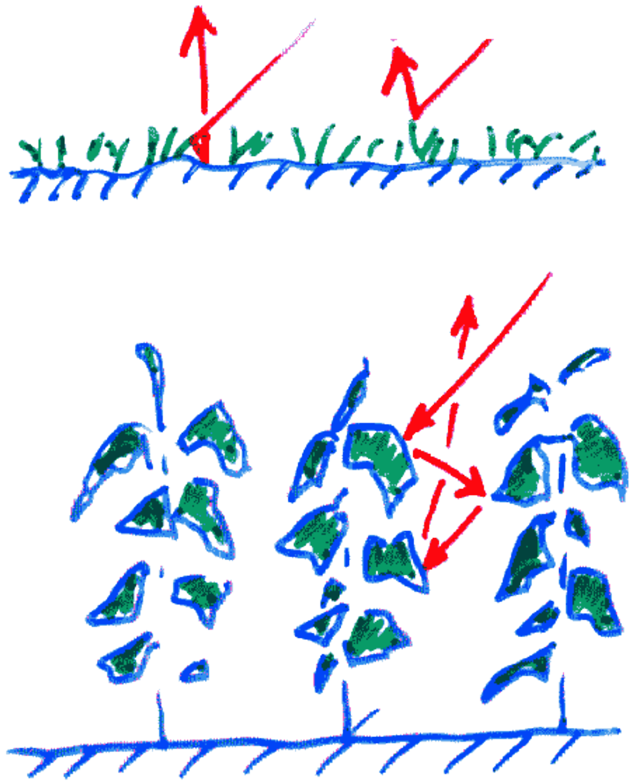


U = urban, S = suburban, R = rural (grass, crops)

Albedo and stand height

Albedo depends on stand height:

- Increased "trapping" of solar radiation with increased height (multiple reflections)
- Individual leaves generally have higher reflectivity than a canopy of the same leaves.



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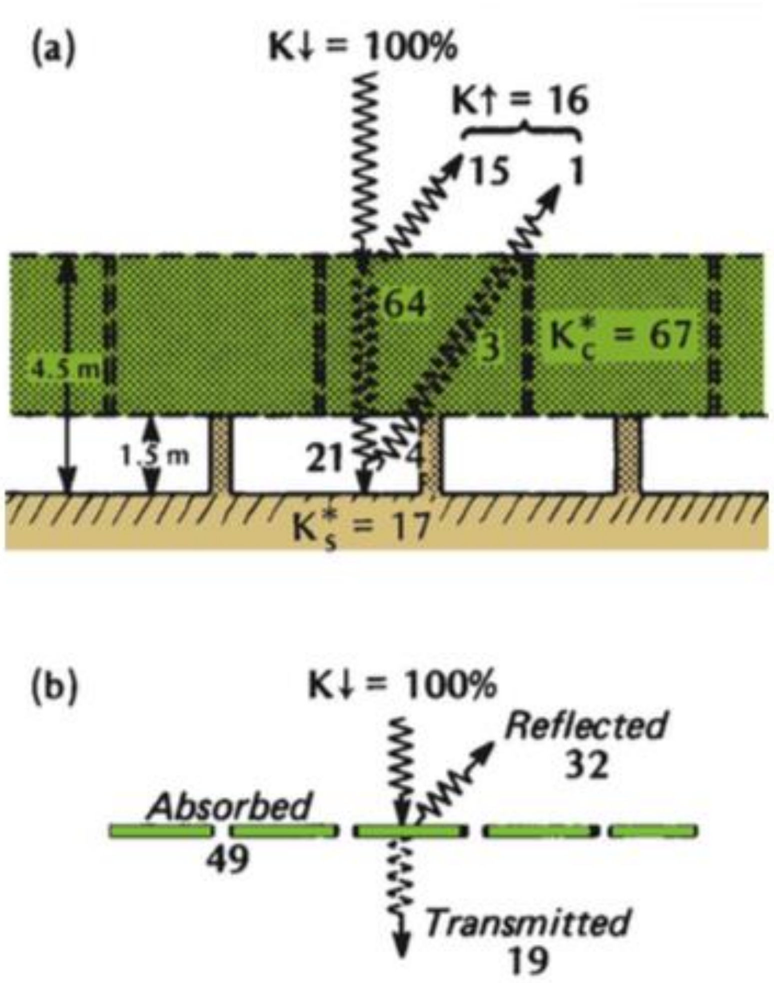
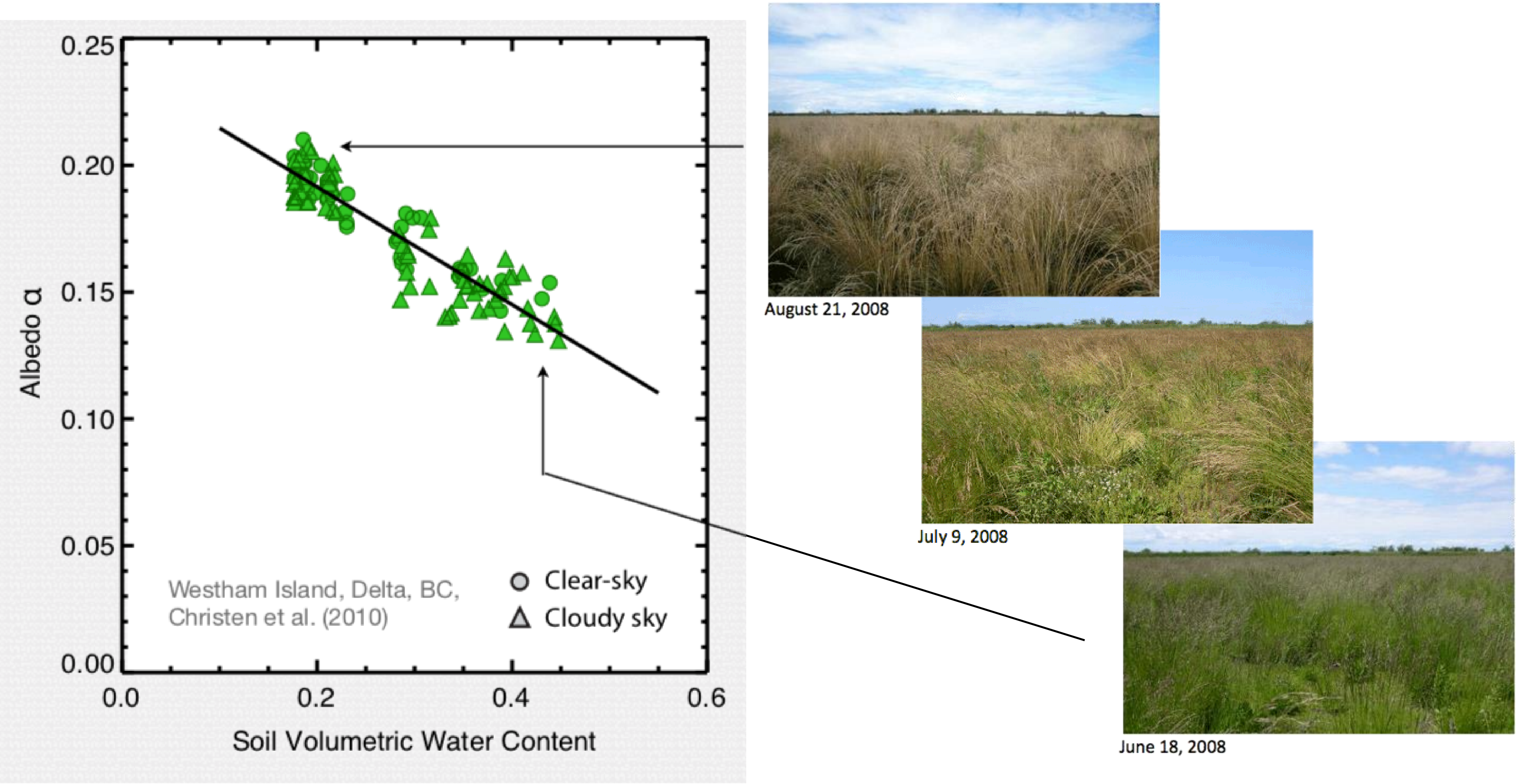


Albedo depends on leaf state and canopy height



Monthly average albedo

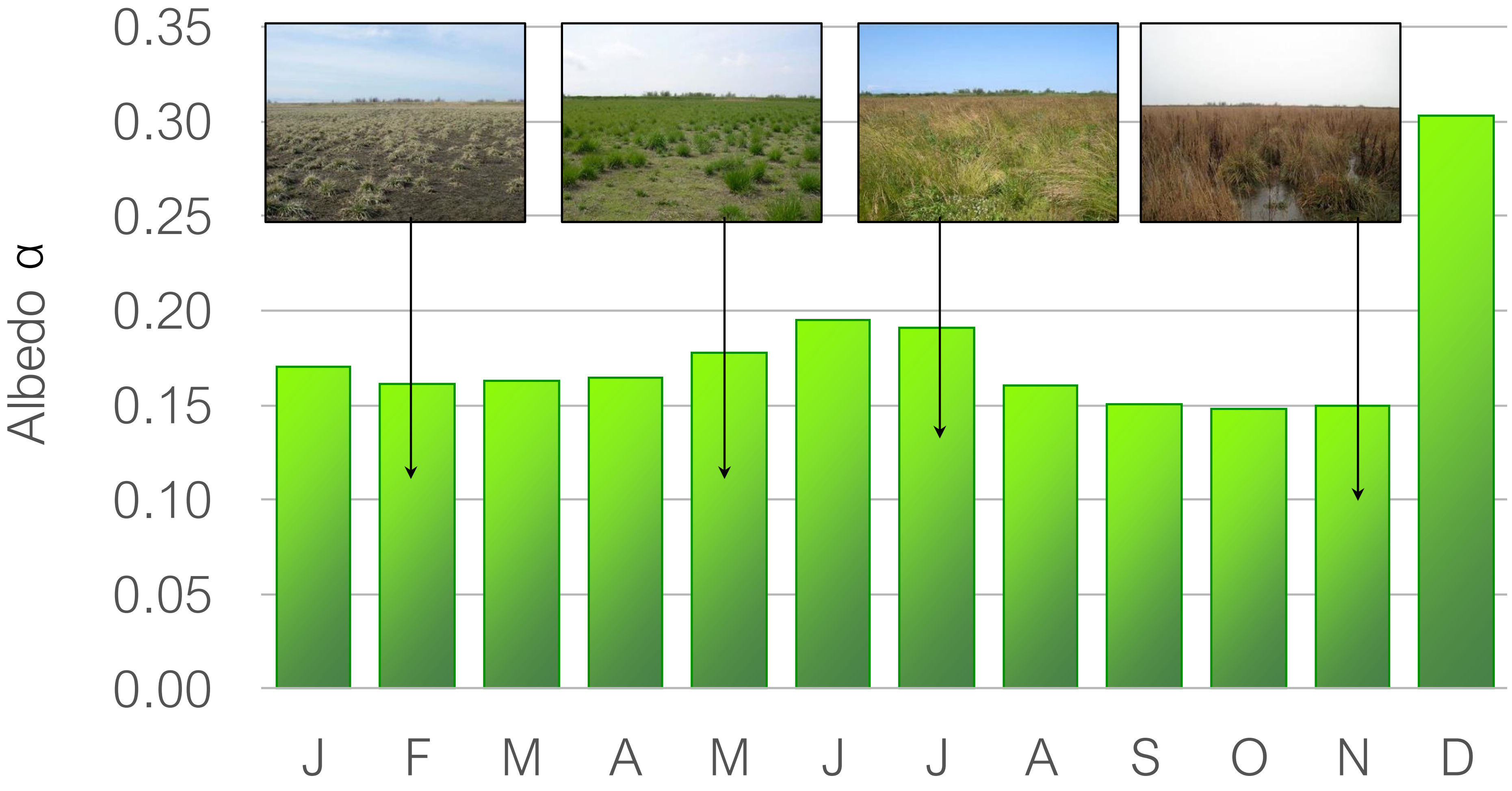



Photo: A. Christen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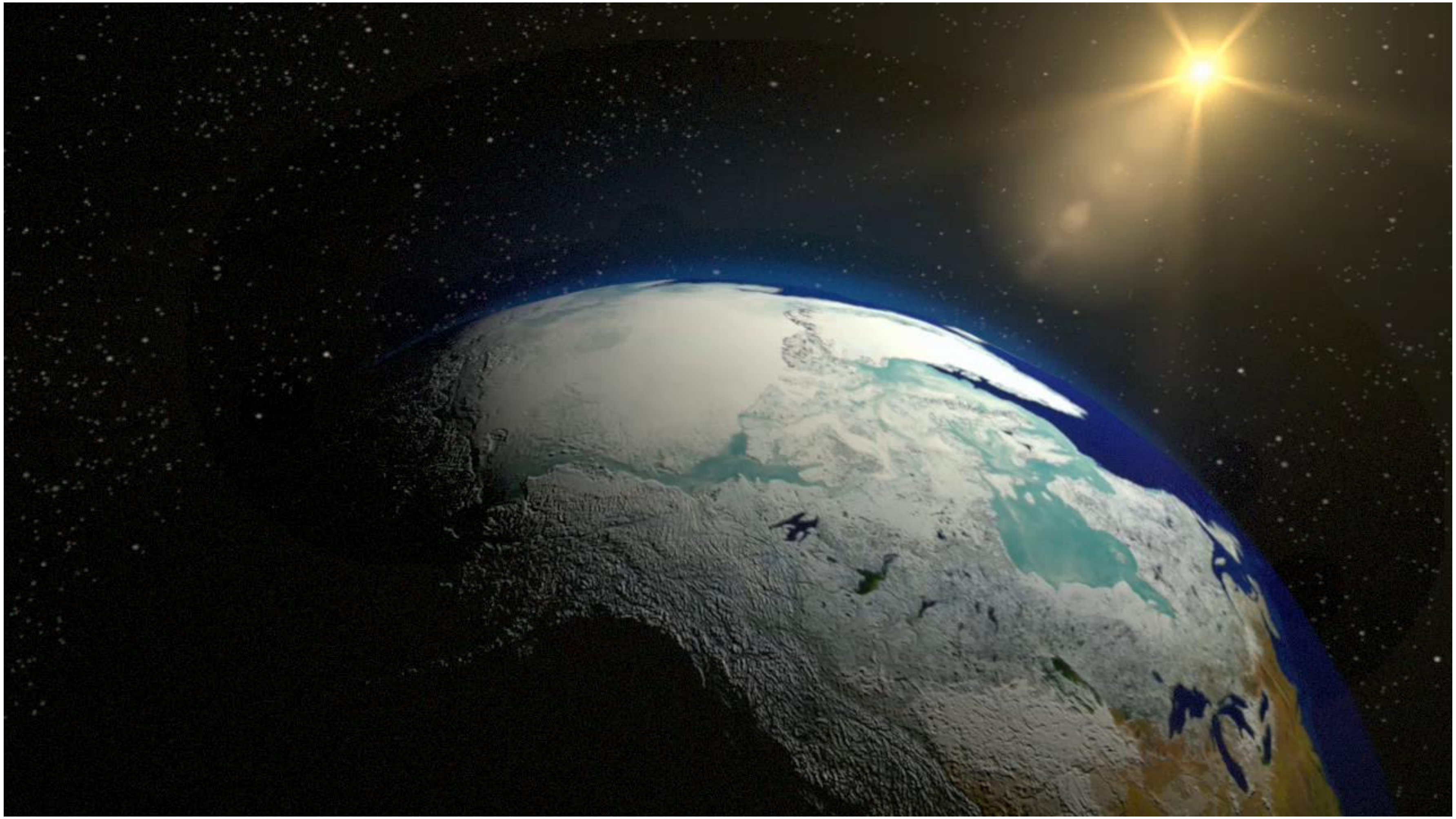
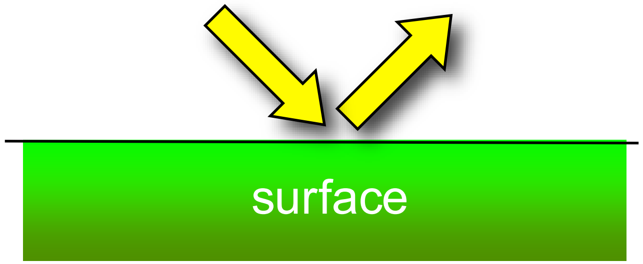
Ice-albedo feedback



Source: https://svs.gsfc.nasa.gov/20021

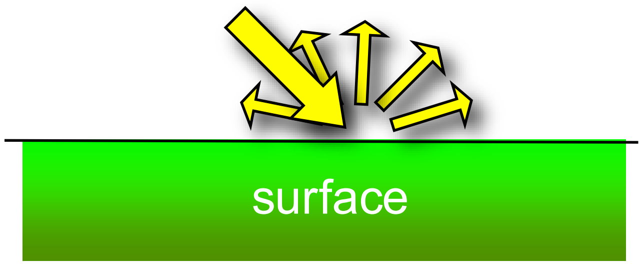
Specular and diffuse reflection

specular



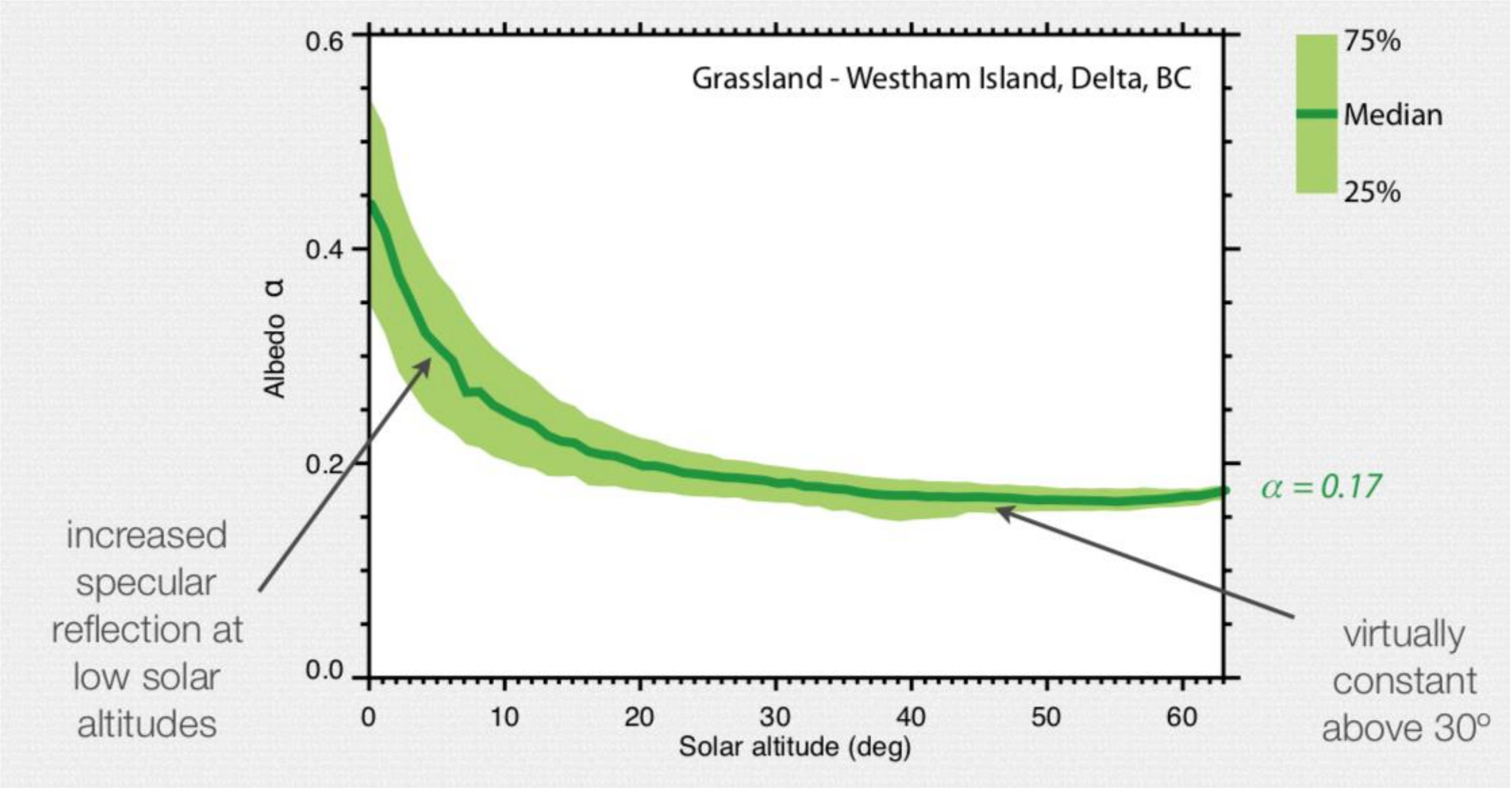
Beam reflected at same angle (like mirror).

diffuse



Beam diffused isotropically (Lambertian).

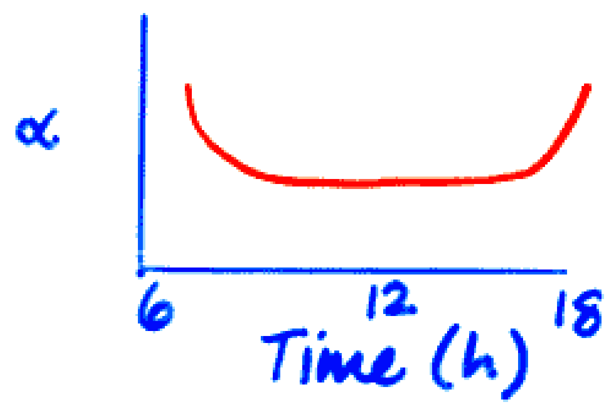
Albedo as a function of solar altitude



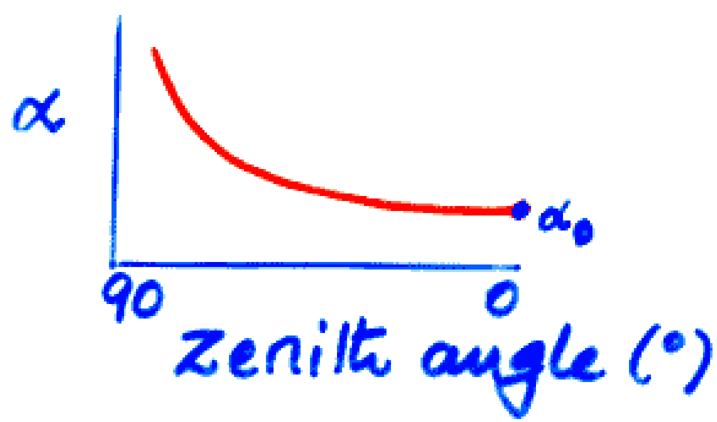
Solar altitude and albedo

Natural surfaces seem to diffuse for $Z < 60°$, and increasingly specular as $Z \rightarrow 90°$. As a simple model we might use:

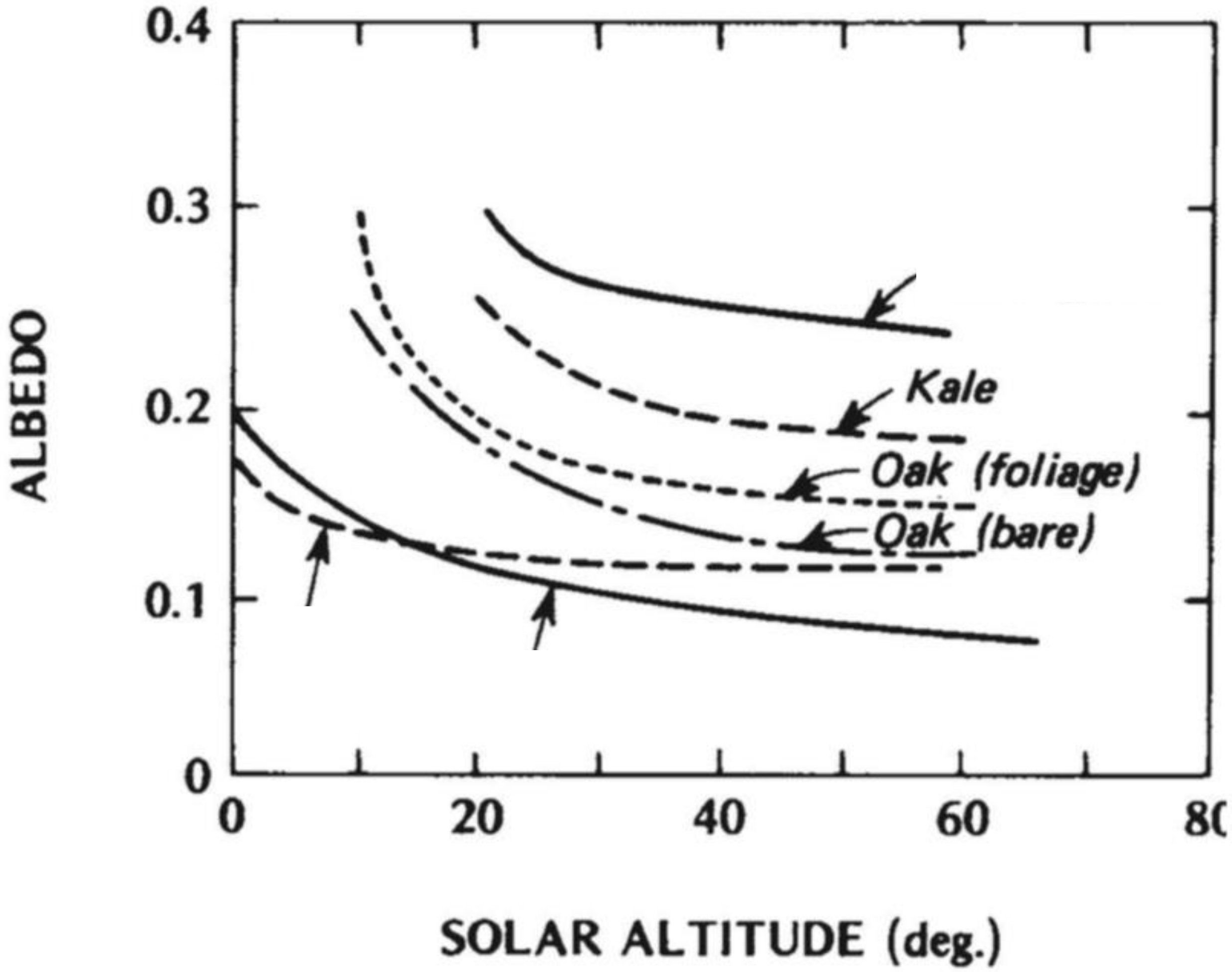
$$\alpha_Z = \alpha_0 + (1 - \alpha_0)e^{-kZ}$$
$$\text{where} \quad k \approx 0.1$$



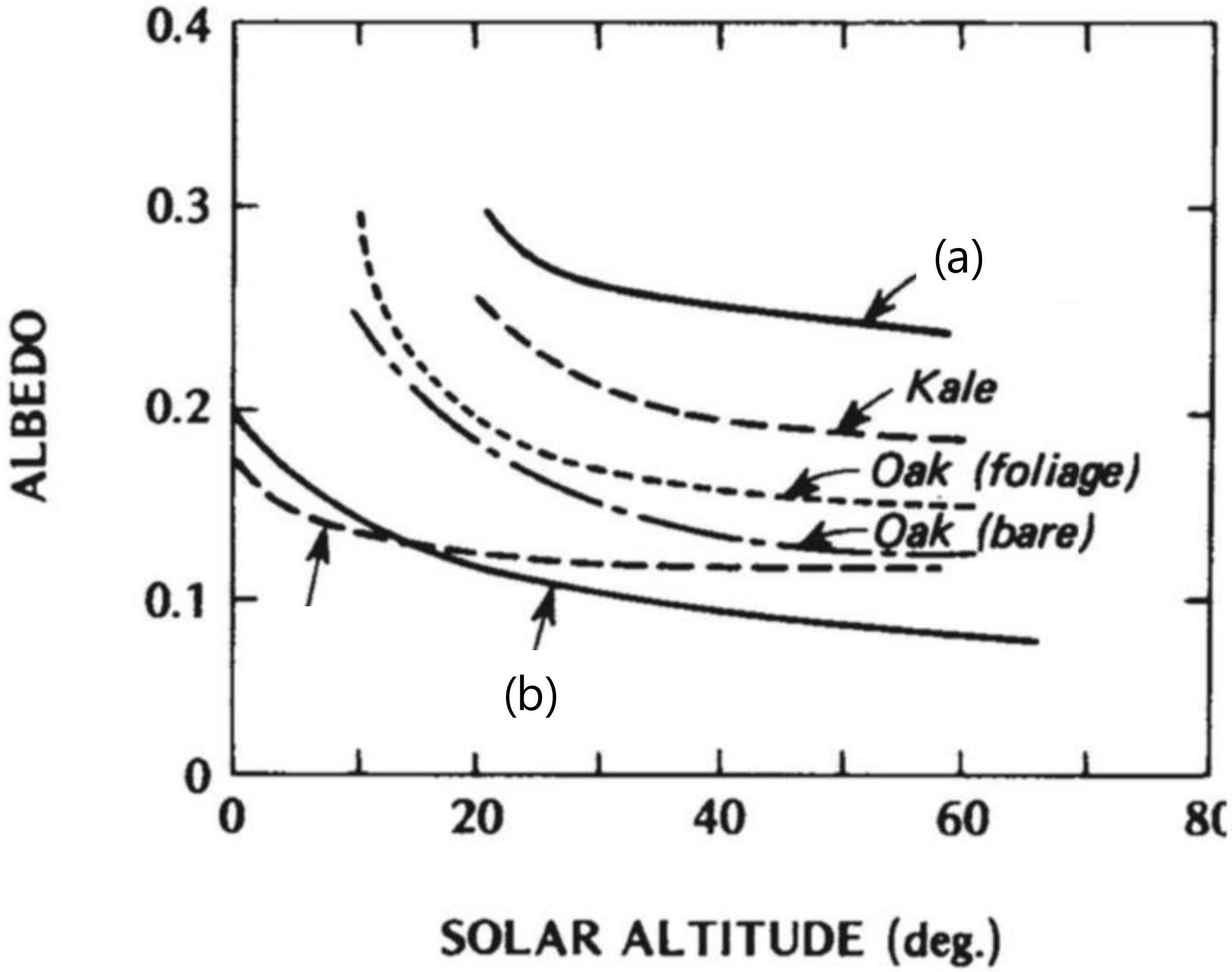
The values in literature usually refer to the **middle part of the day (value at noon or an average for a subset around midday) or the albedo calculated from the daily totals of irradiance and reflectance**.



Solar altitude, canopy height and albedo



Which line (a or b) corresponds to a taller canopy?



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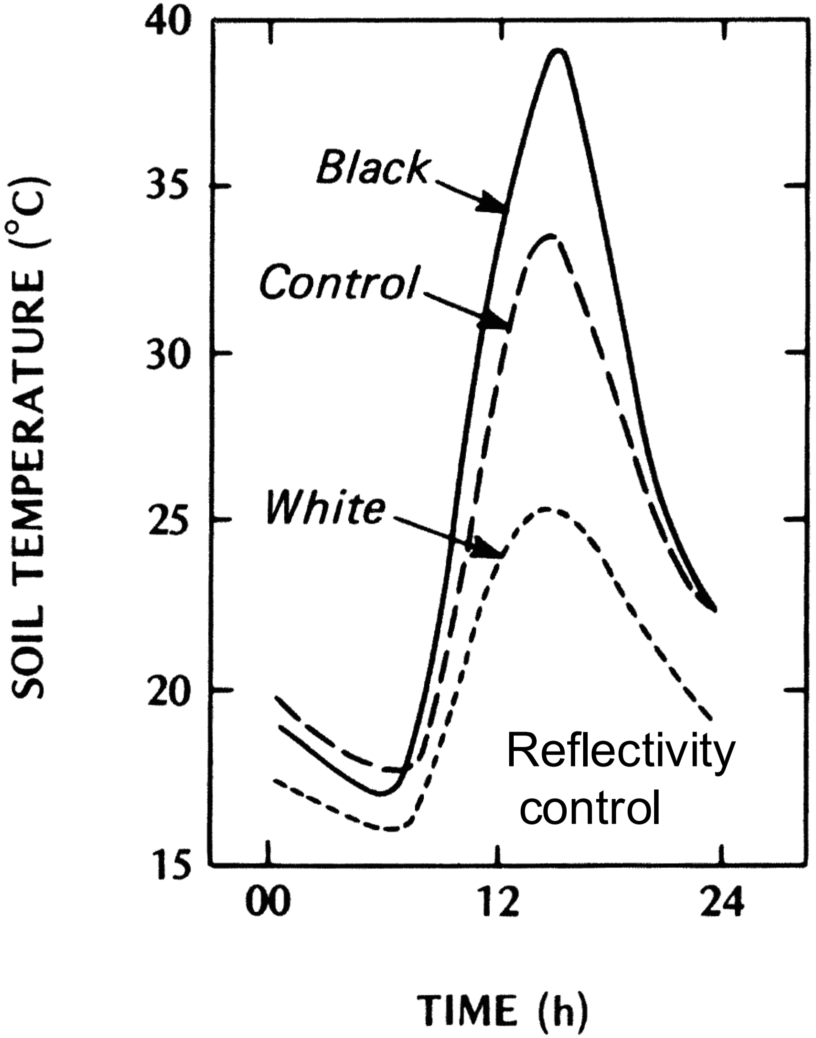
Control and modification.

There are mainly two ways to modify the short-wave radiative surface properties:

(1) **Reflectivity control** - Changing the surface color in various wavelengths by painting the surface (e.g. roof-tops), or wrapping the surface in white or dark plastic (agriculture).

(2) **Geometry control** - Changing the microtopographic feature of a setting to increase or reduce absorption.



Albedo control

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Weatherwatch: Why cooling white roofs cause neighbours to swelter

Climate hack used to reflect heat results in less rain and higher temperatures in surrounding regions, study finds

...fs law would help cool

...rough proposes bylaw requiring white roofs

...31, 2010 | 10:53 AM ET Comments 186 Recommend 80

All new roofs would be white under a Montreal borough's proposed bylaw aimed at taking advantage of a white roof's cooling effects.

Mayor François Croteau of Rosemont-La Petite-Patrie wants to make white roofs mandatory on new buildings. Roofs requiring repairs would have to be painted white as well.

...vorld white


BANCO
POPULAR
BANCO
POPULAR
BANCO
POPULAR
TELEBANCO
Unicasa
FUNDUS
LEPANTO LEPANTO
LEPANTO


Photo: A. Christen

Take home points

- As short-wave radiation reaches a surface, part of it is reflected - can be quantified by **spectral reflectivity** and the **reflection coefficient** (called **albedo** for short-wave)
- Albedo is controlled by the material, 3D form, the leaf state and the presence of snow.
- Reflection can be **specular** and/or **diffuse** - and most natural surfaces become increasingly specular at low solar altitudes.
- Changing the albedo of a surface (material, geometry) is a powerful tool to microclimate **modification**.