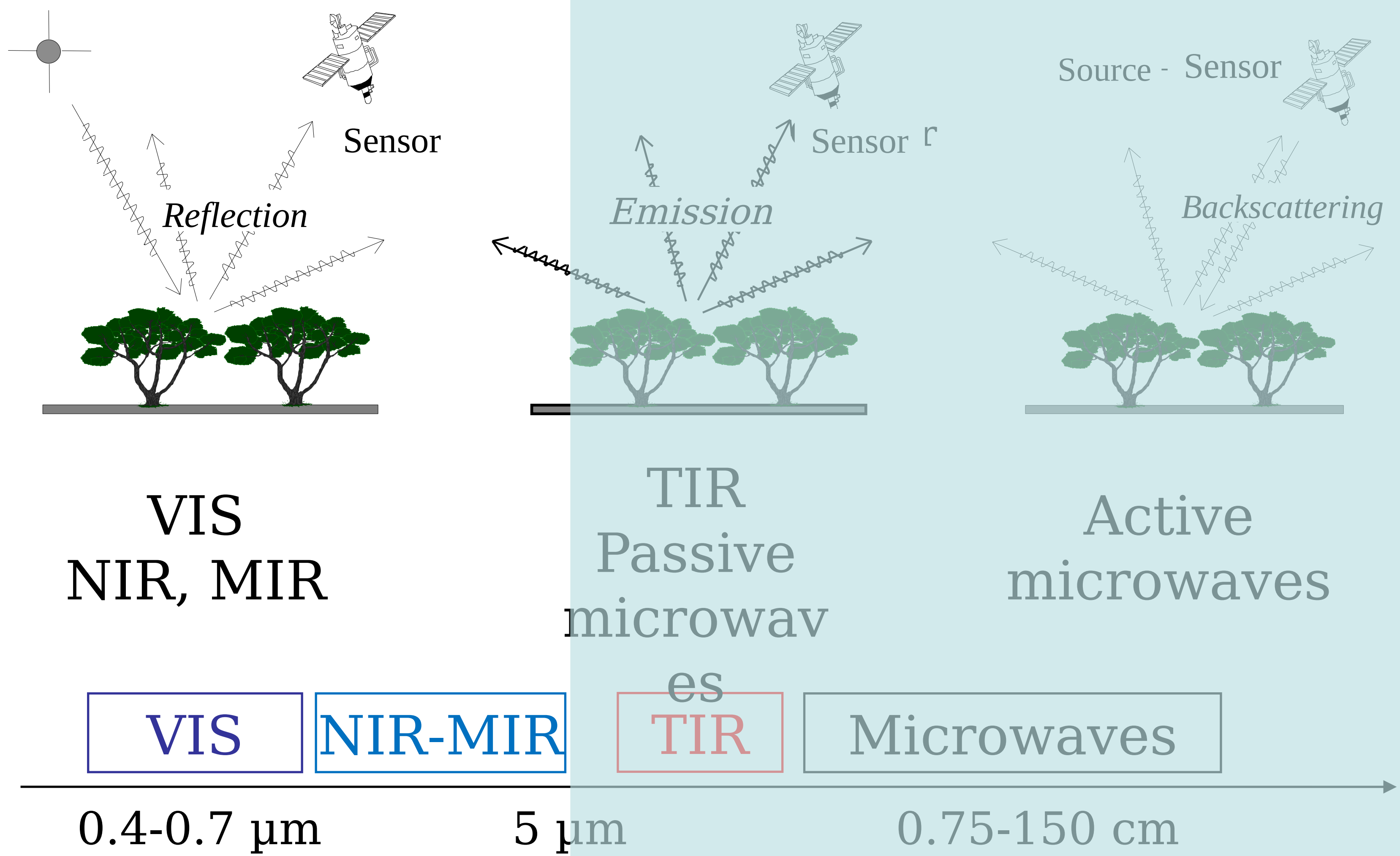
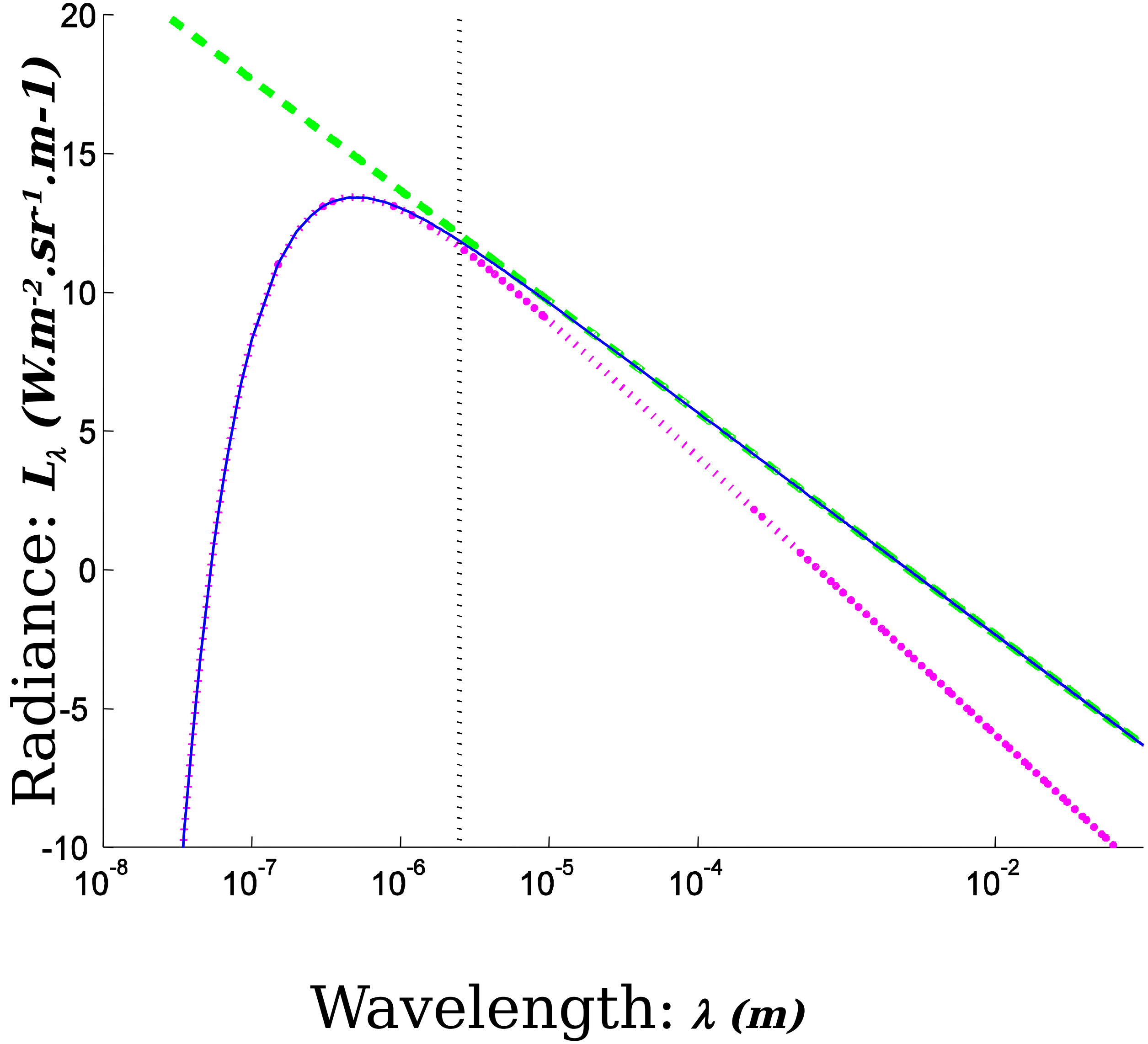
Optical Domain
0.4 μm – 5 μm

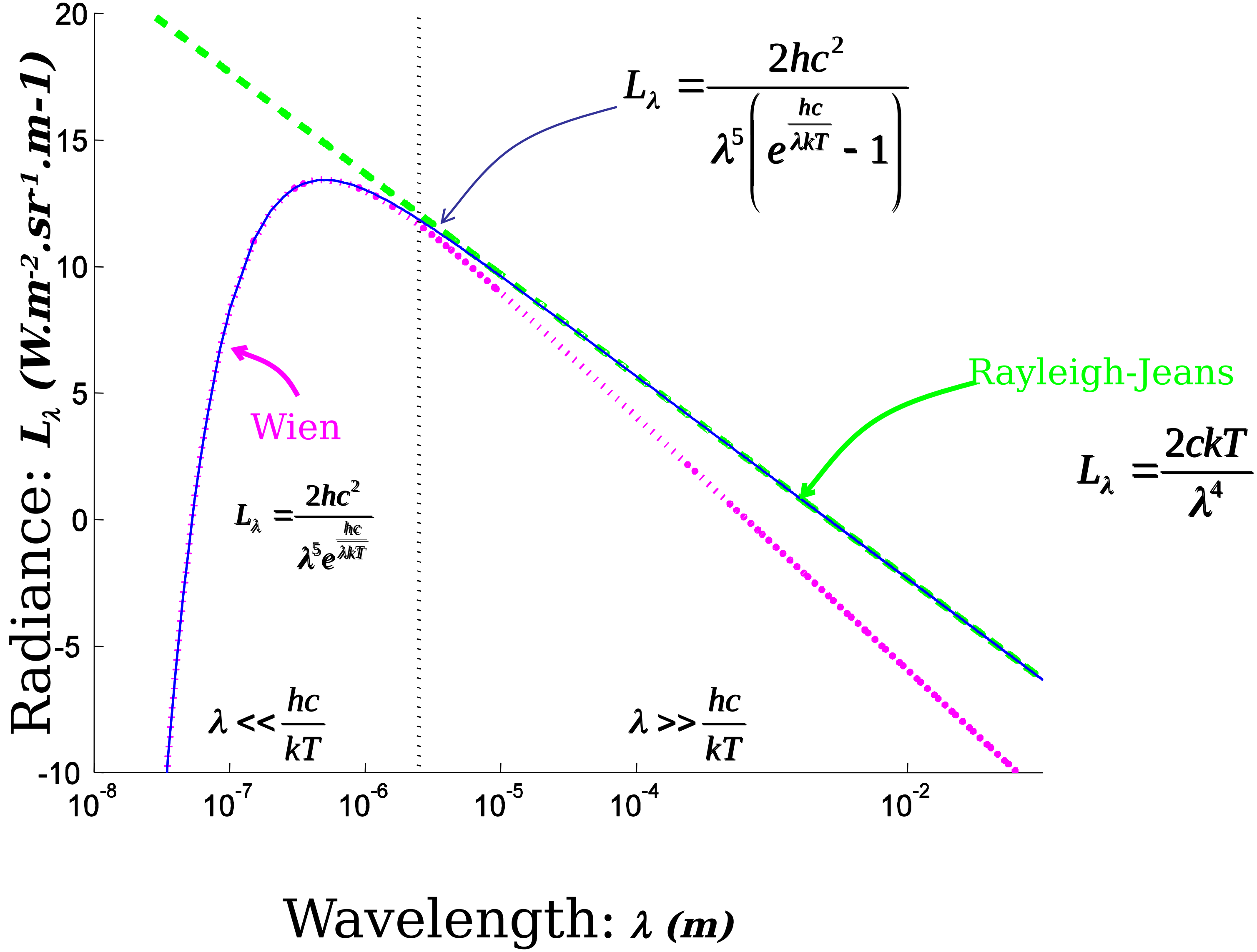
Observation Modes



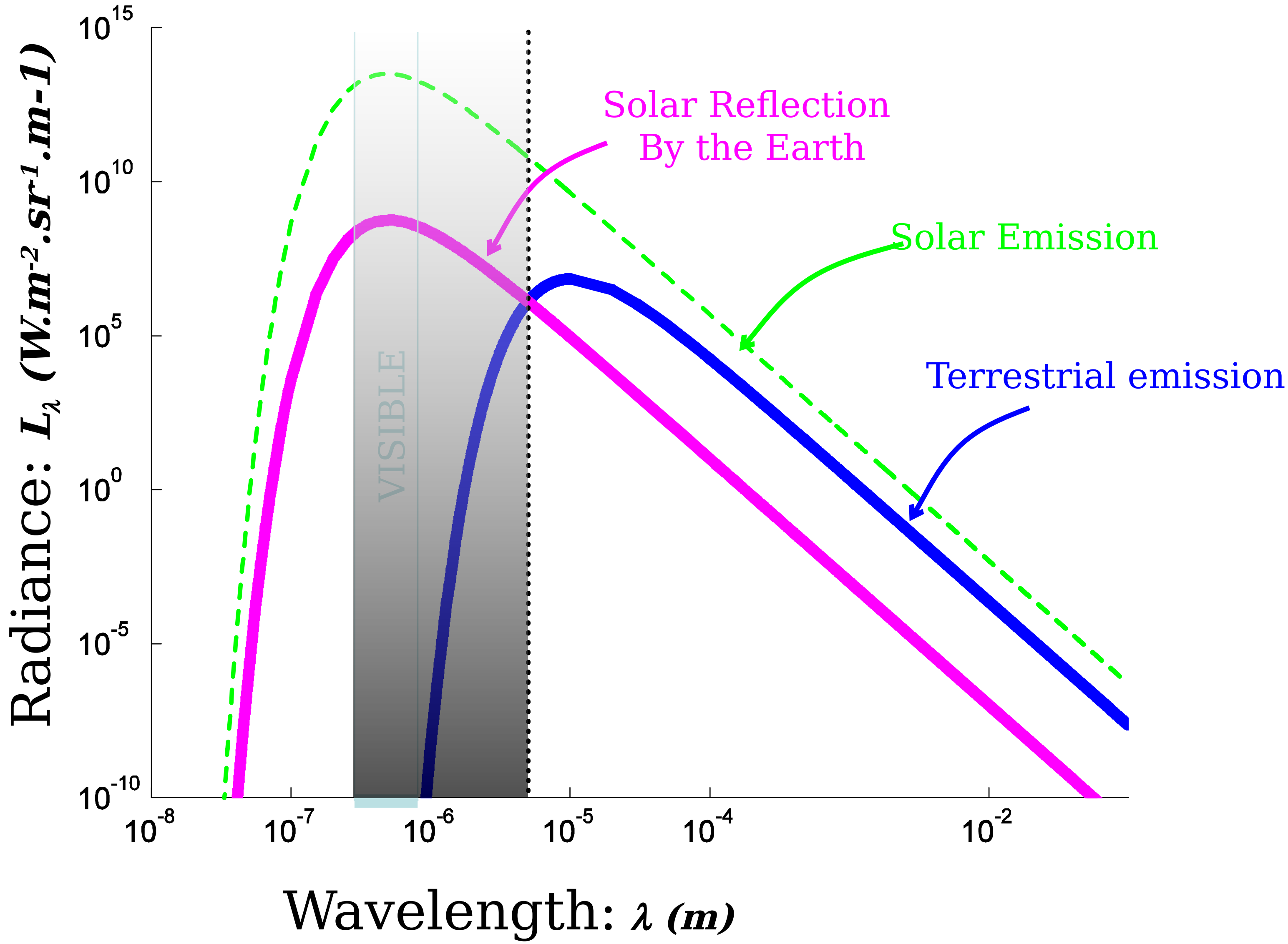


Radiance: L_λ (W.m^{-2}.sr^{-1}.m-1)
20
15
10
5
0
-5
-10
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-2}
Wavelength: λ (m)

Black body radiation
Rayleigh-Jeans and Wien approximations



OPTICAL DOMAIN



Solar irradiance received by the Earth

adiance emitted by the Sun (Black Body): $L = \int_0^\infty L_\lambda \, d\lambda$ *(W.m-2.sr-1)*

Emittance totale : $M = \pi L = \sigma T^4$ *(W.m-2)*

Cste de Stefan-Boltzmann: $\sigma = 5.67\ 10^{-8}$ SI

otal power emitted by the Sun: $\Phi = \sigma T_{sol}^4 \, 4\pi R_{sol}^2$

rradiance received by the Earth: $E = \dfrac{\sigma T_{sol}^4 \, 4\pi R_{sol}^2}{4\pi D_{ST}^2} = \dfrac{\sigma T_{sol}^4 \, R_{sol}^2}{D_{ST}^2}$

A.N.: $R_{sol} = 696\ 10^6$ m
$D_{ST} = 150\ 10^9$ m
$T_{sol} = 5800$ K

$\Rightarrow$ $E = 1380\ W.m^{-2}$

Some magnitudes….

Radiation emitted by the Sun (per Surface unit): $M = \sigma T^4 \quad 64\ MW.m^{-2}$

(σ = 5.67 10^{-8} SI, T_{sol} = 5800 K)

Max. Emission wavelength: $\lambda_{max} = \dfrac{2.898\,.10^{-3}}{T}$ ***500 nm*** *(□ in the **visible**)*

Irradiance received by the Earth: $E = \dfrac{\sigma T_{sol}^4\, 4\pi\, R_{sol}^2}{4\pi\, D_{ST}^2} = \dfrac{\sigma T_{sol}^4\, R_{sol}^2}{D_{ST}^2}$ 1380 W.m^{-2}

(R_{sol} = 696 10^6 m, D_{SE} = 150 10^9 m)

Earth: ~~Disc *($S=\pi R^2$)*~~ but ***Sphere*** *($S=4\pi R^2$)* ⇒ ***E 345 W.m^{-2}***

Absorbs / Emits: 240 W.m^{-2} ⇒ $T = \sqrt[4]{\dfrac{240}{\sigma}}$ ***-18°C***

Max. emissison wavelength.: $\lambda_{max} = \dfrac{2.898.10^{-3}}{T}$ ***10 µm*** *(□ in **InfraRed**)*

Electromagnetic radition at the Earth Surface

THE EARTH SURFACE:

- ***Receives*** radiation in the ***visible***
- ***Emits*** radiation in the ***InfraRed***

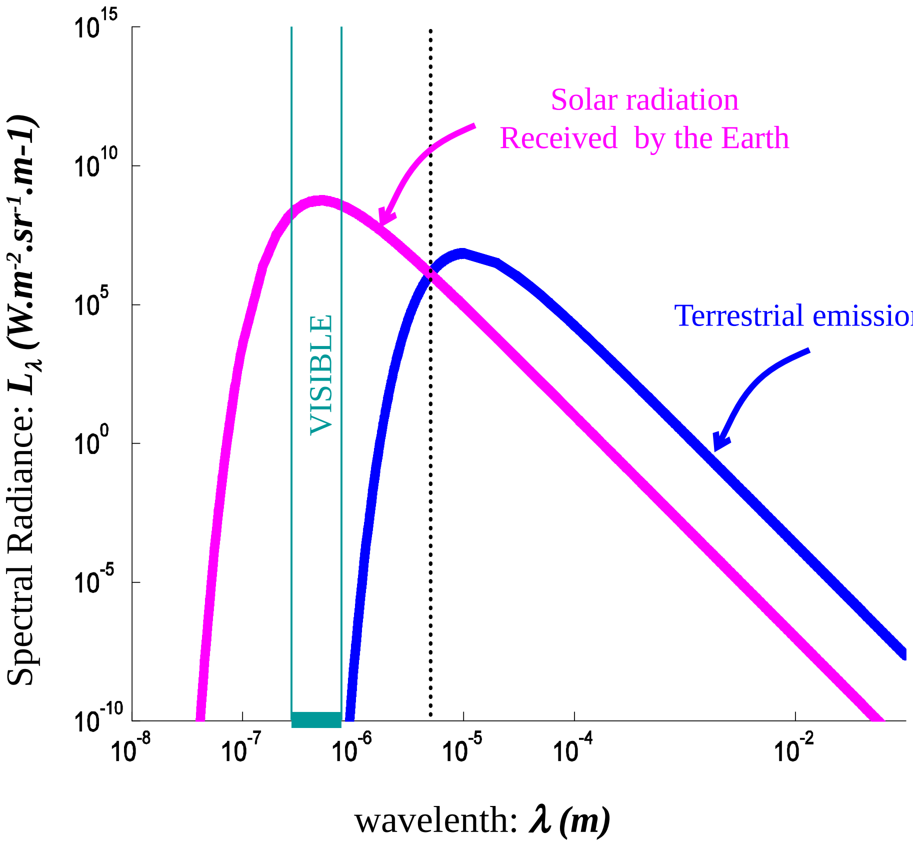
THE ATMOSPHERE:

- ***Transparent*** for ***visible radiation***
- ***Absorbs InfraRed radiation***

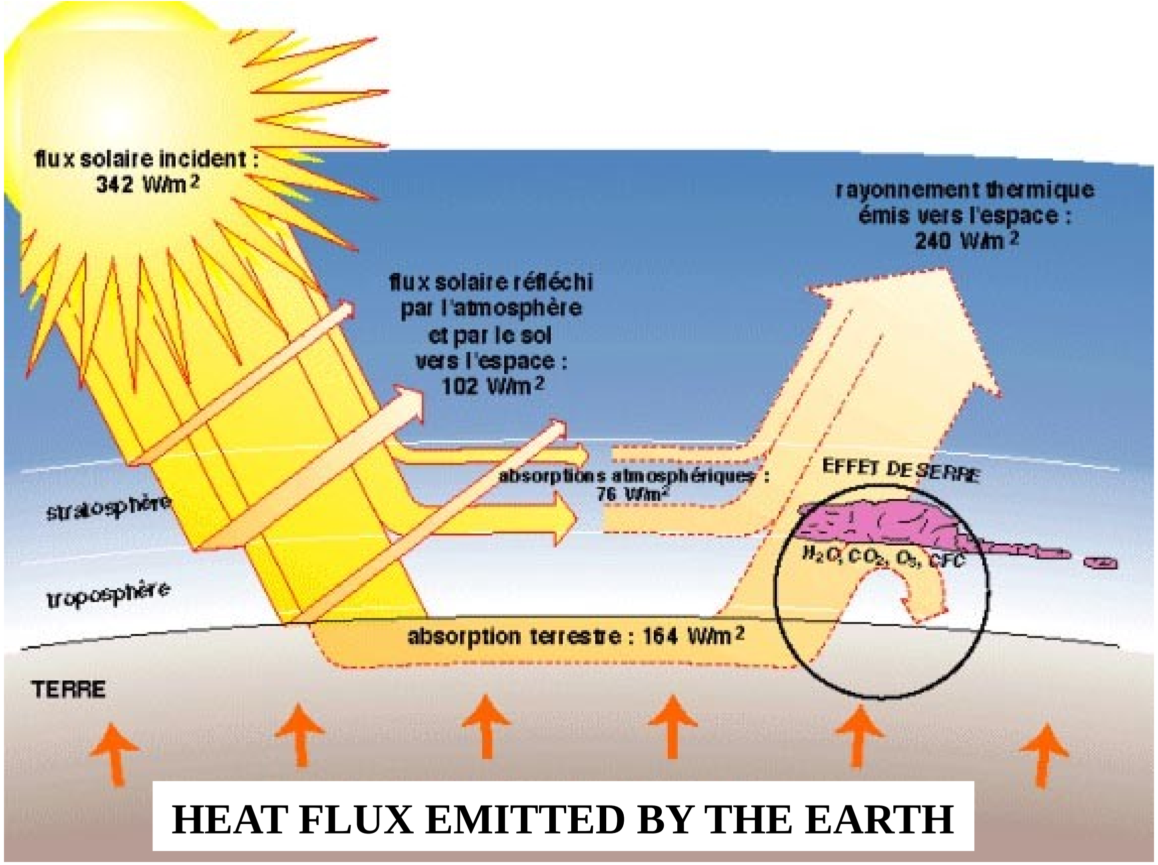
Due to « Greenhouse » gases:

H_2O, CO_2, NH_4, ….

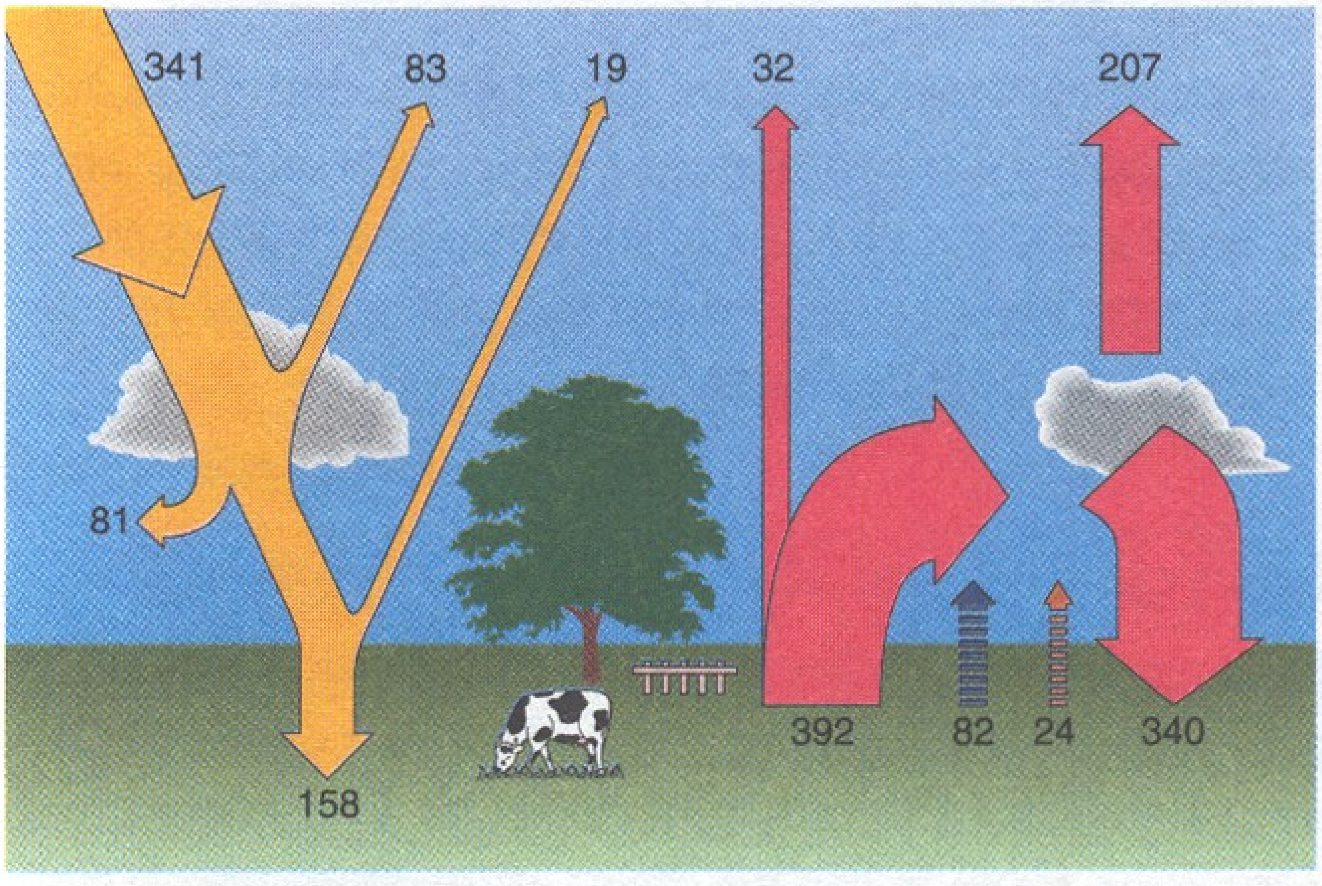
$T_{surf.\ Terre}$: ~~-18°C~~ ***15°C***



Greenhouse effect



GREENHOUSE EFFECTS



Source: R. Sadourny, 1994

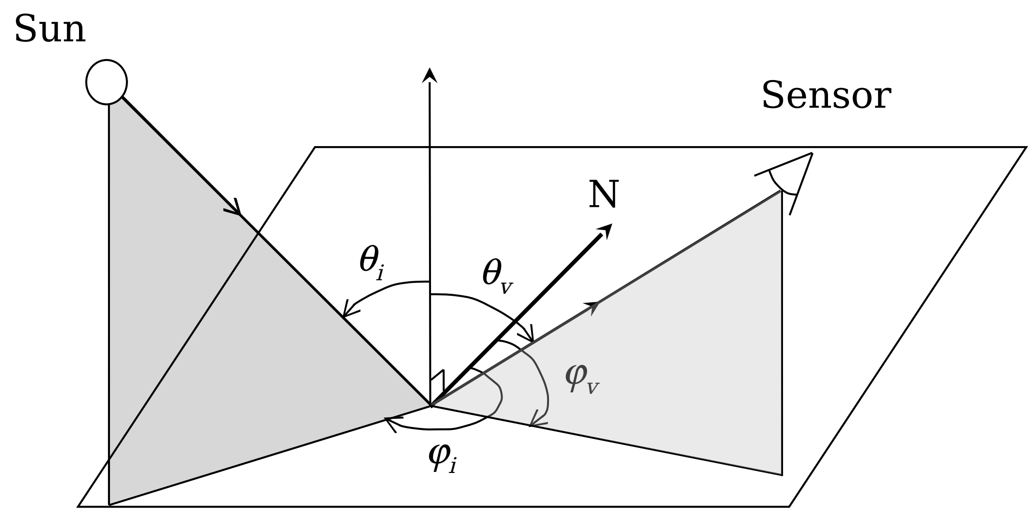
Optical measurements (0.4 – 5 µm)

(Reflection of Solar Radiation)

éflectance: characterize the studied surface

Bidirectionnal réflectance :

$$\rho(\theta_i,\varphi_i,\theta_v,\varphi_v,\lambda)=\frac{L_r}{E_i}=\frac{L_r}{L_i\cos\theta_i d\Omega_i}$$



Albedo: $$a=\frac{\int_{hém.} L_r\cos\theta_v d\Omega_v}{\int_{hém} L_i\cos\theta_i d\Omega_i}=\frac{M}{E_i}$$

Reflectance Factor:

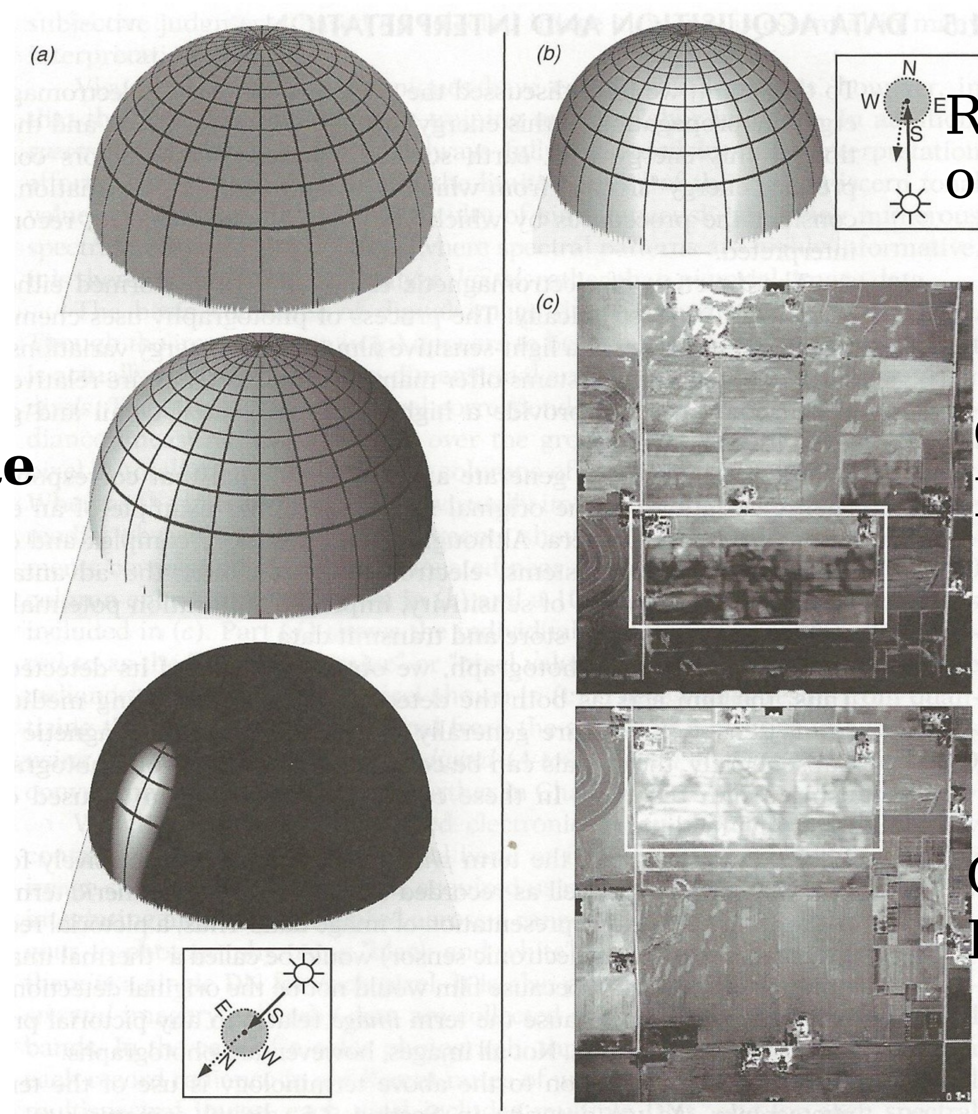
$$\rho_b=\frac{\rho_r}{\rho_r^{ref}}\frac{L_r}{L_r^{ref}}=\frac{\pi L_r}{E_i} \quad \text{with} \quad E_i=L_{sol}\frac{\pi R_{sol}^2}{D_{ST}^2}\cos\theta_i \quad \Rightarrow \quad \boxed{\rho_b=\frac{1}{L_{sol}R_{sol}^2}D_{ST}^2\frac{L_r}{\cos\theta'}}$$

xemples of bidirectional reflectances

lambertian

intermediate

Spécular



Reflectance Simulation
of a crop field

Crop fields
Pictured from the Nor

Crop fields
Pictured from the Sout

Source: Lillesand *et al.,* 20

Specular effet over a water surface

Source: Lillesand *et al.,* 20

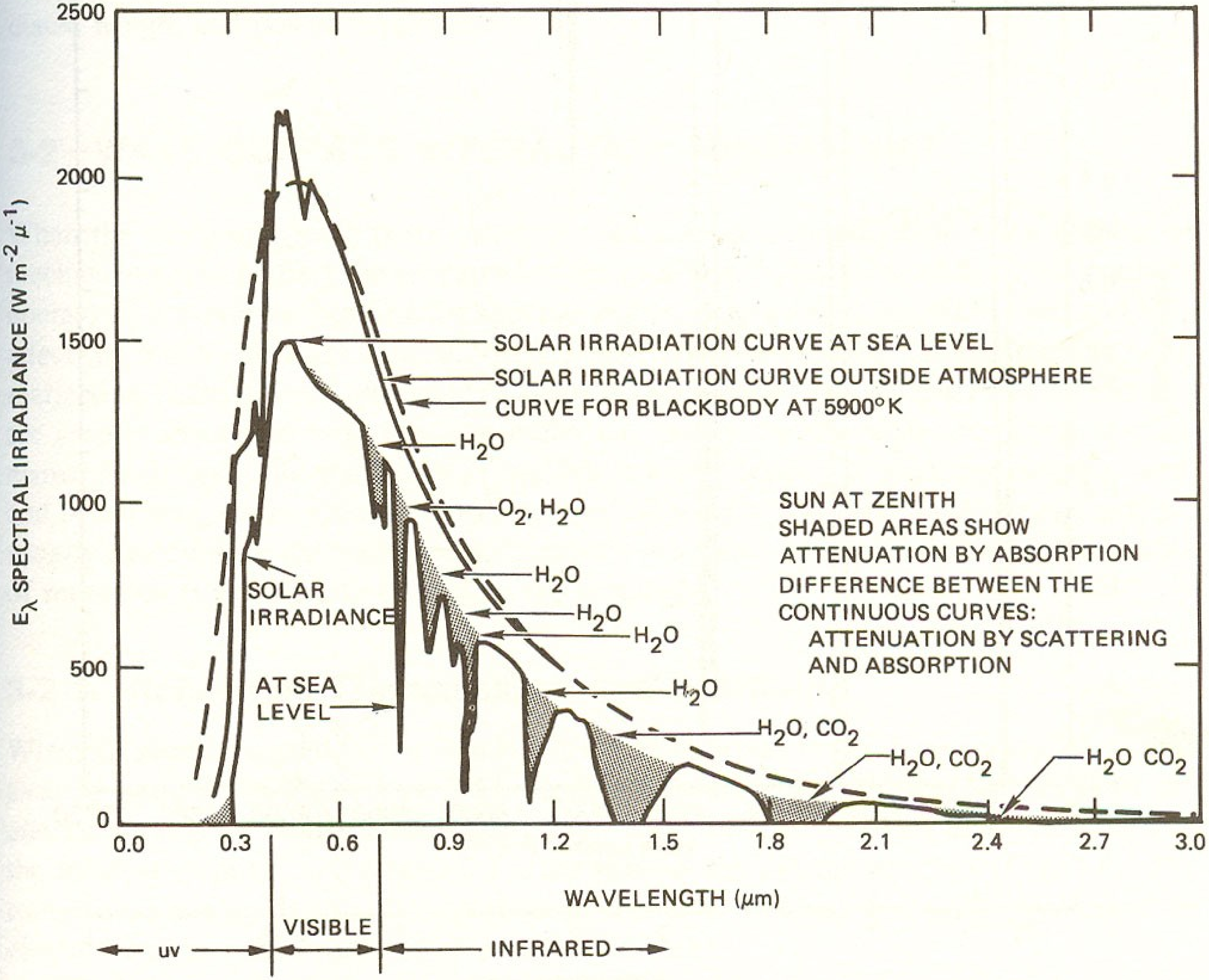
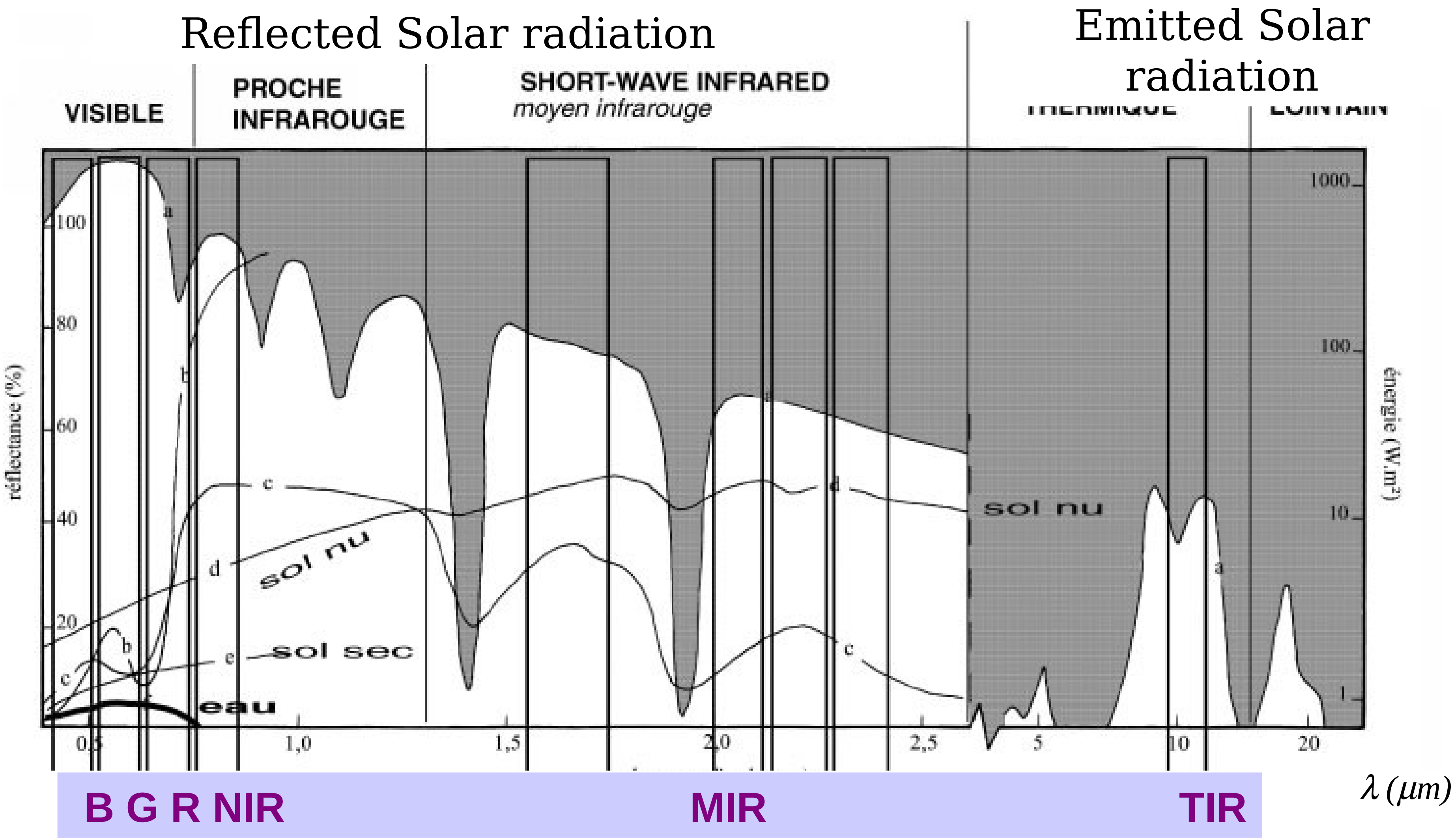
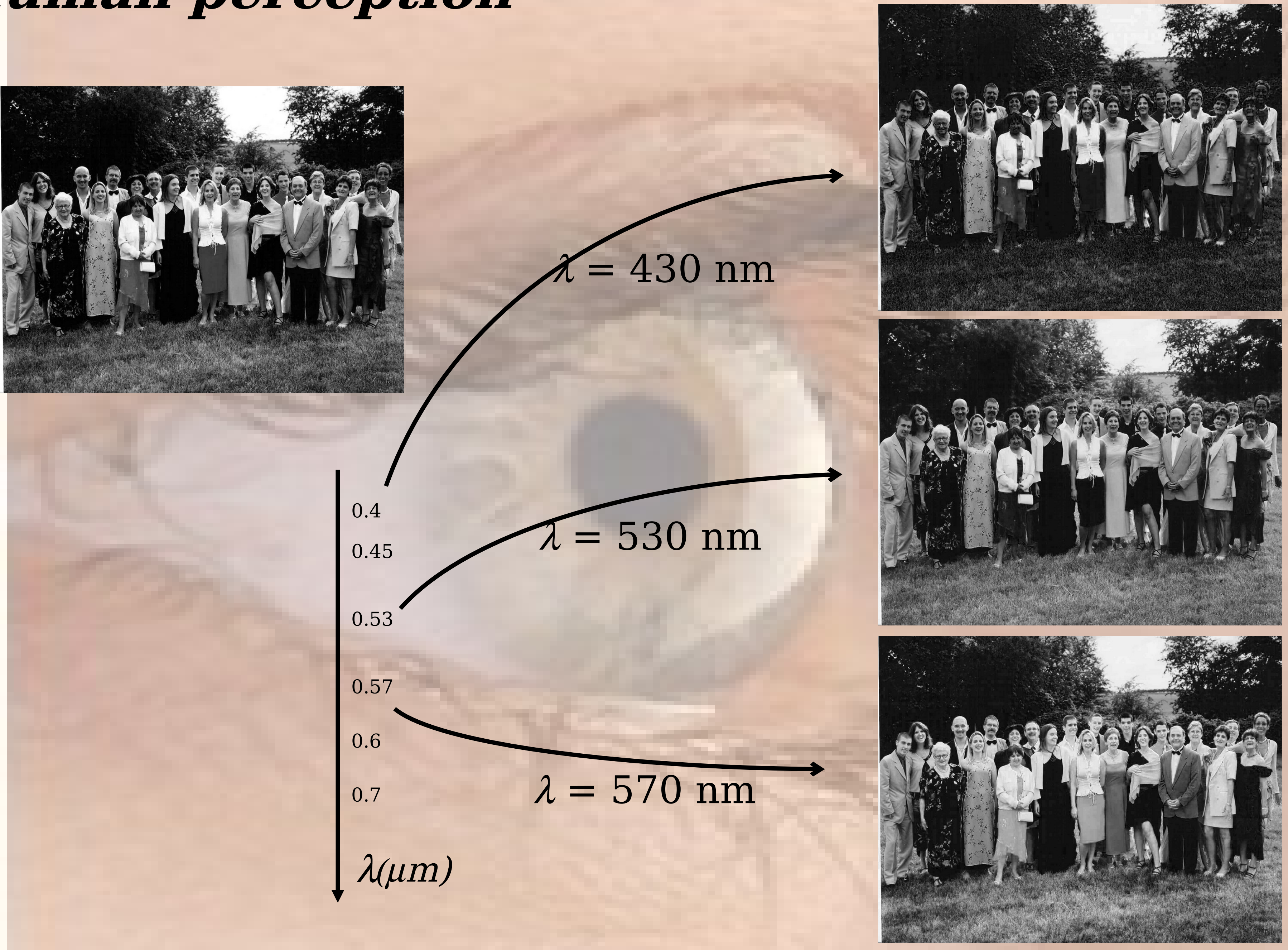


Figure 3-2. Sun illumination spectral irradiance at the Earth's surface. (From Chahine, et al. 1983.)

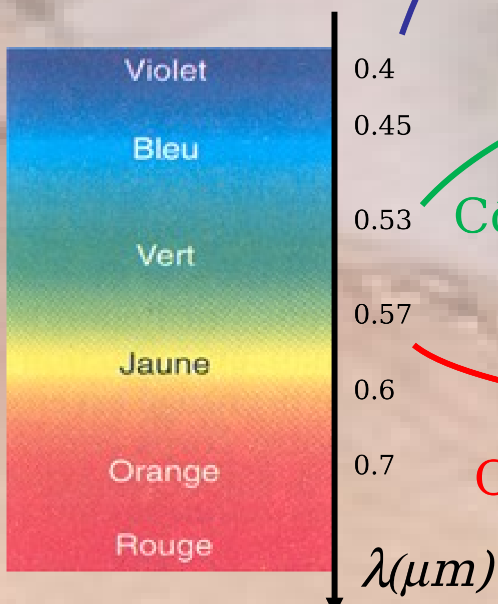
SPECTRAL SIGNATURES



Human perception



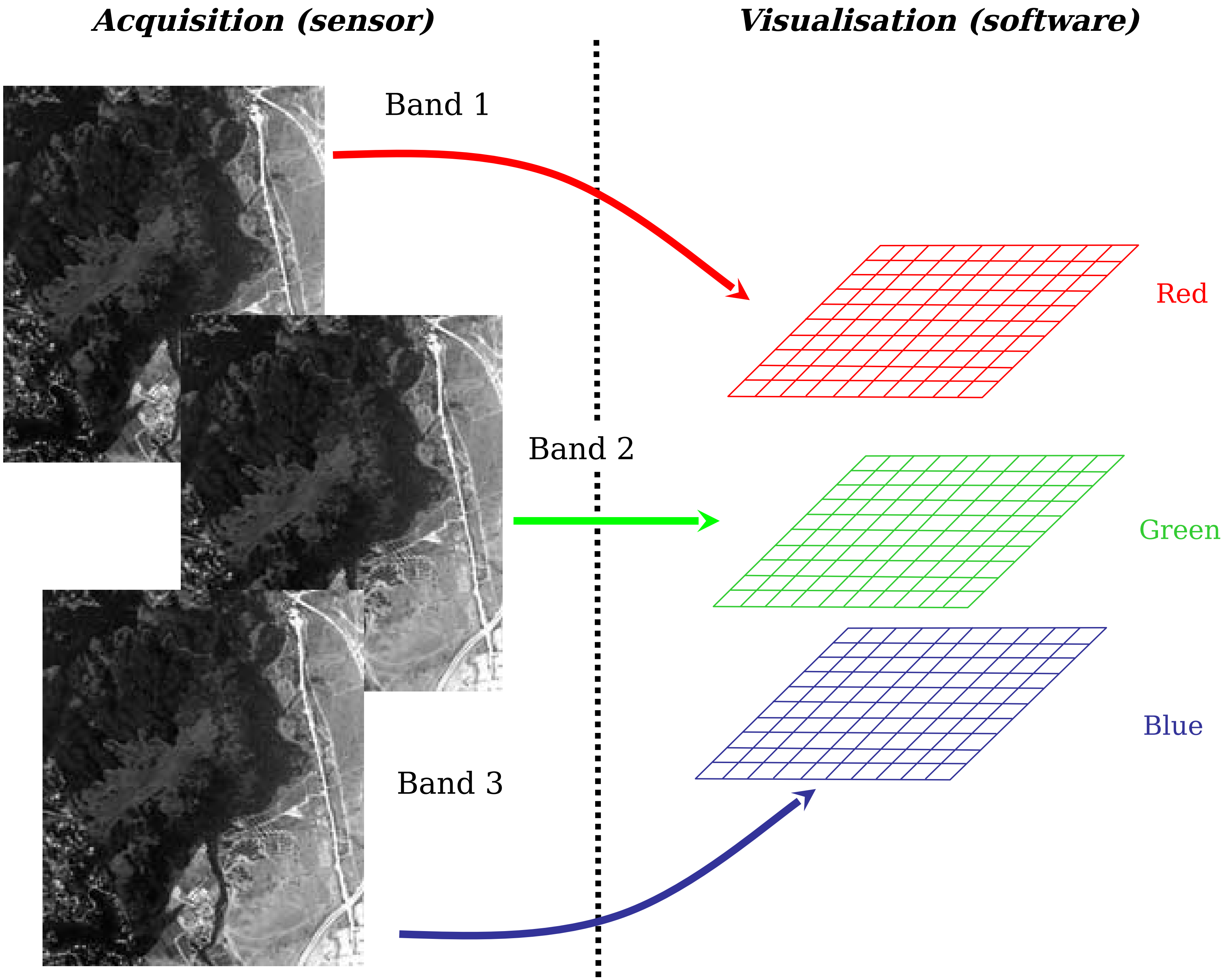
Human perception

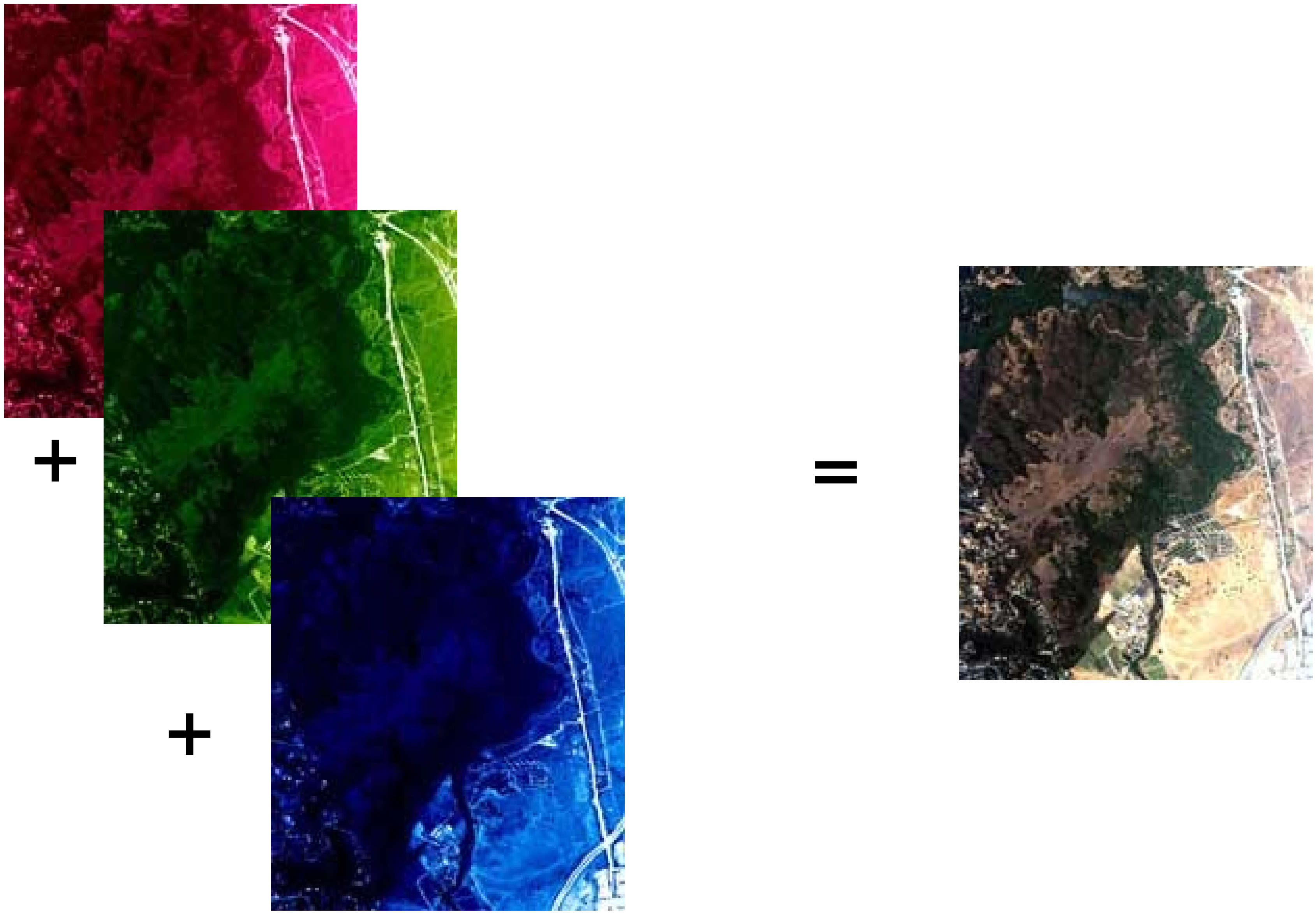


Cône B (5%): λ = 430 nm

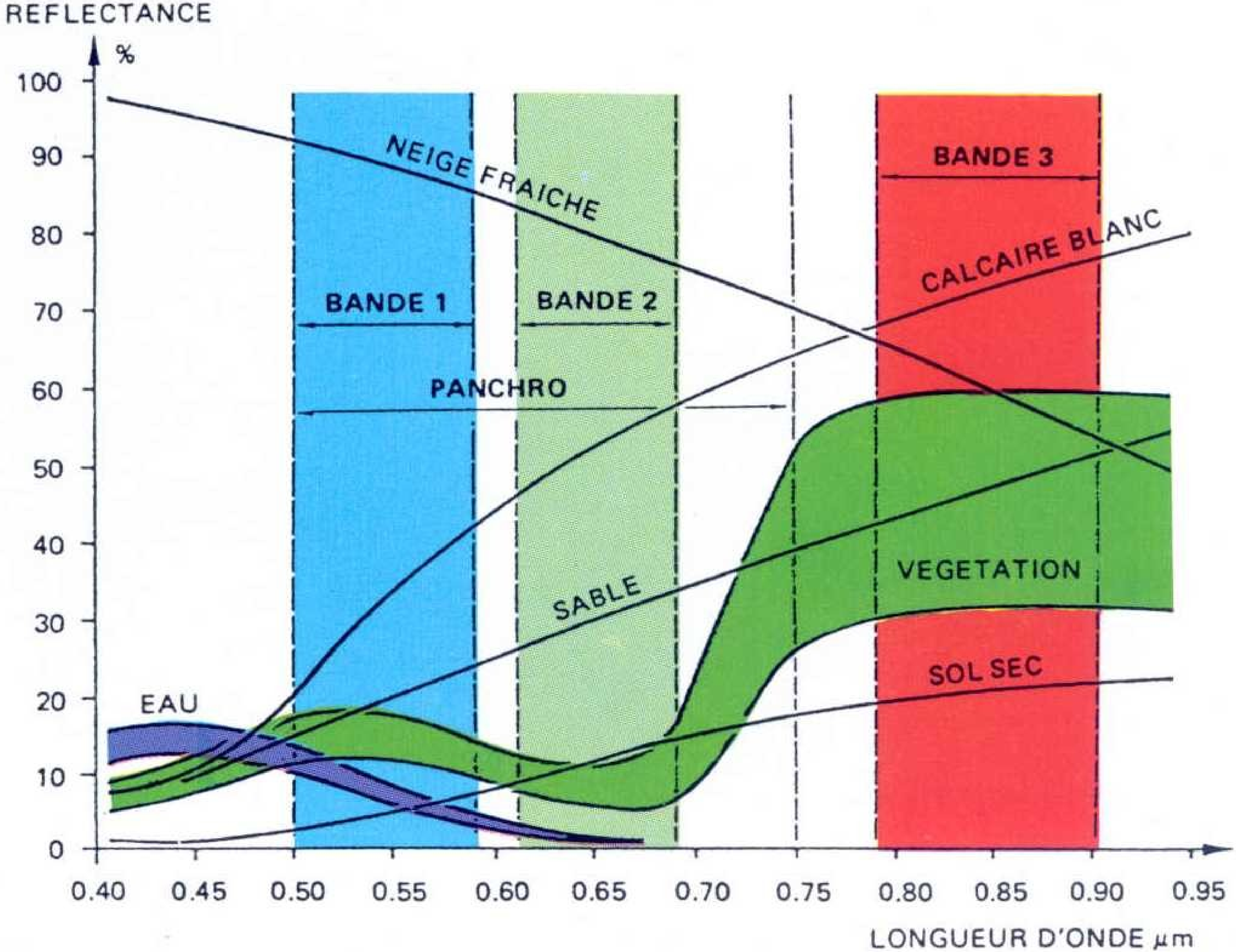
Cône G (35%): λ = 530 nm

Cône R (60%): λ = 570 nm

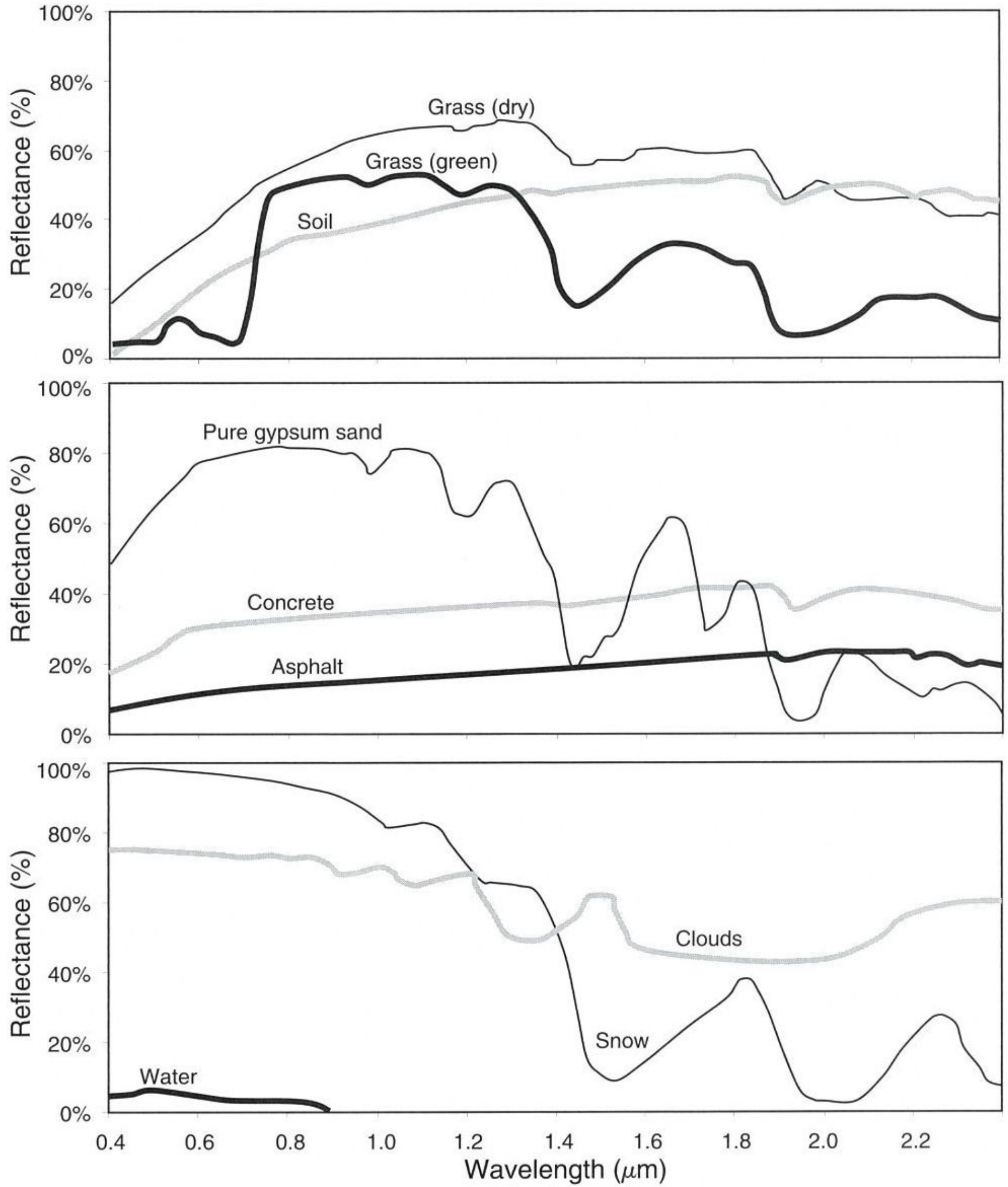

Acquisition (sensor)
Visualisation (software)
Band 1
Band 2
Band 3
Red
Green
Blue



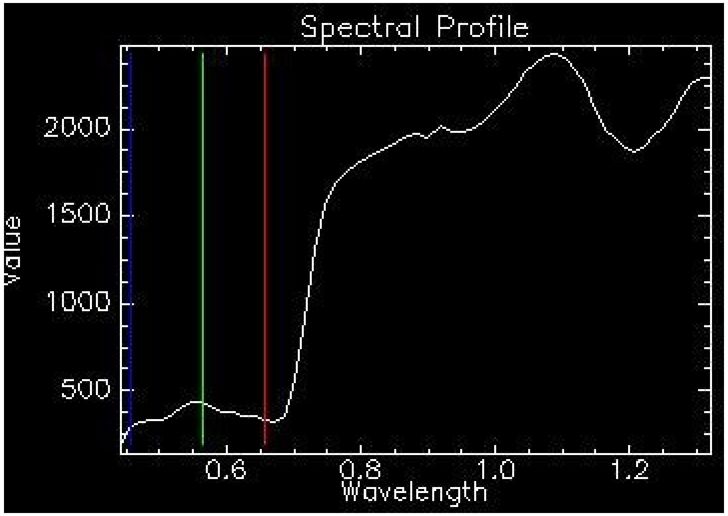
Spectral signatures of different types of surfaces



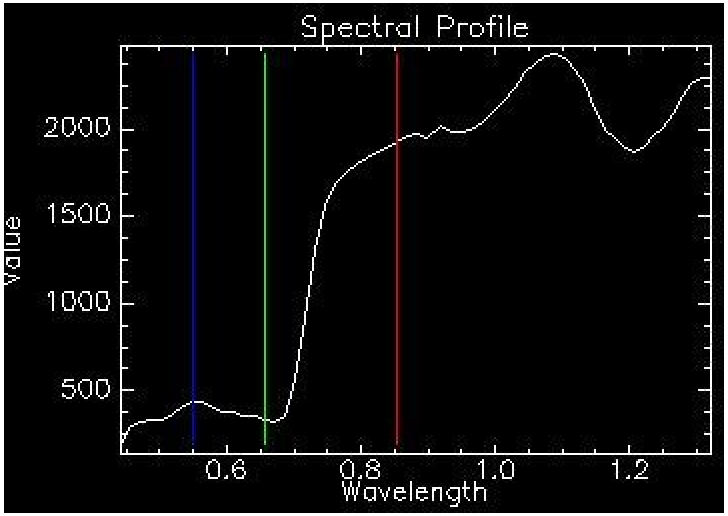
Spectral signatures of different types of surfaces



Source: Lillesand *et al.,* 20



Spectral Profile
Value
Wavelength
2000
1500
1000
500
0.6
0.8
1.0
1.2

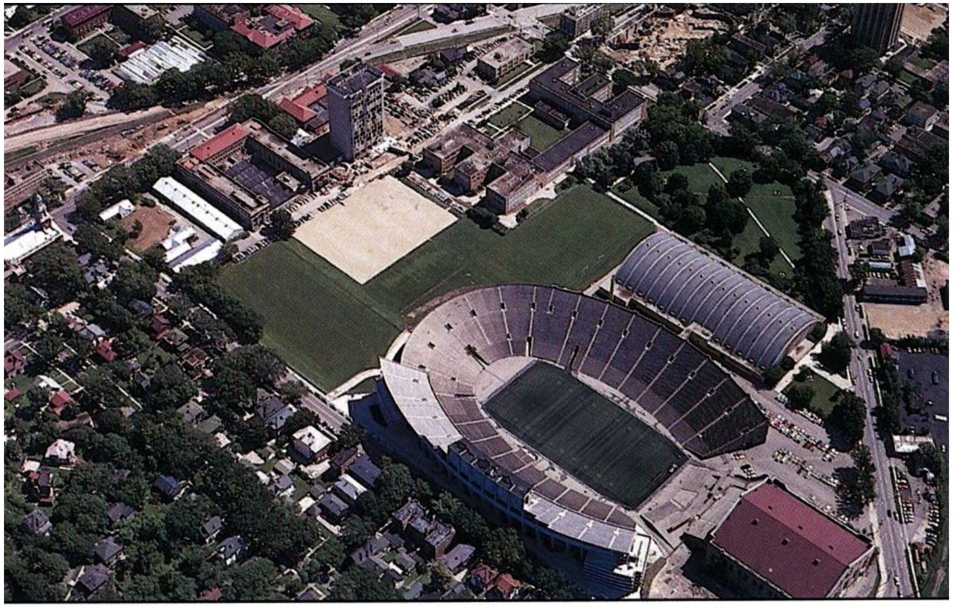


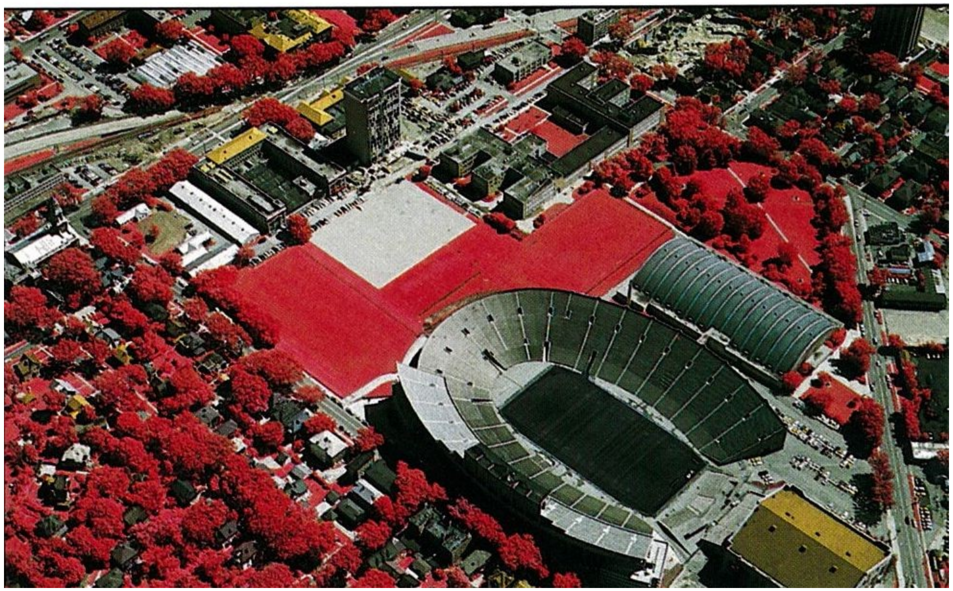
Spectral Profile
Value
Wavelength
2000
1500
1000
500
0.6
0.8
1.0
1.2

DISCRIMINATION of the VEGETATION with the InfraRed

Source: Lillesand *et al.,* 20

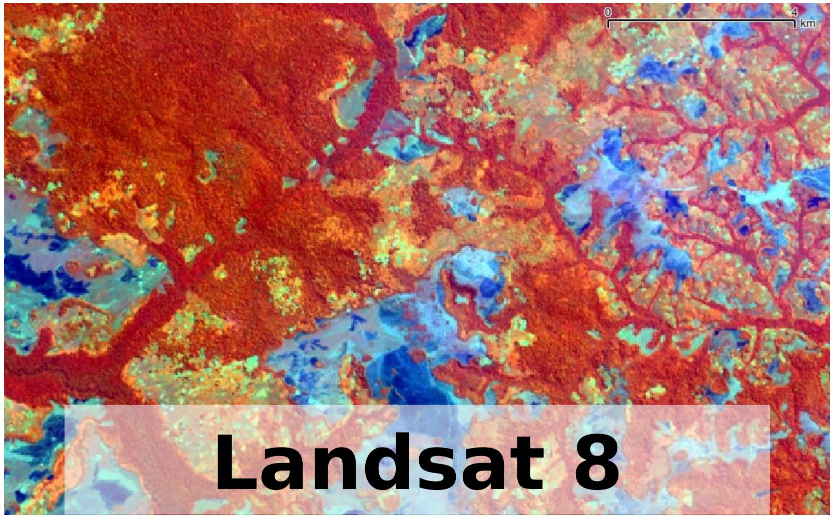
DISCRIMINATION of the VEGETATION with the InfraRed

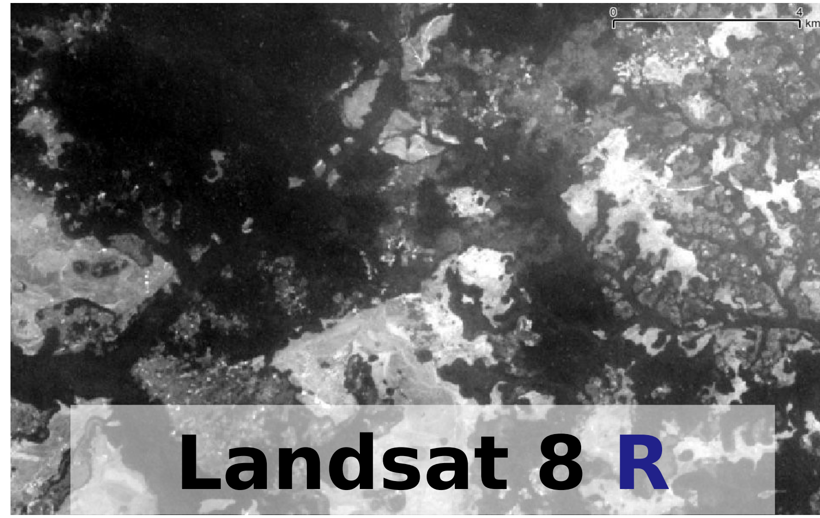


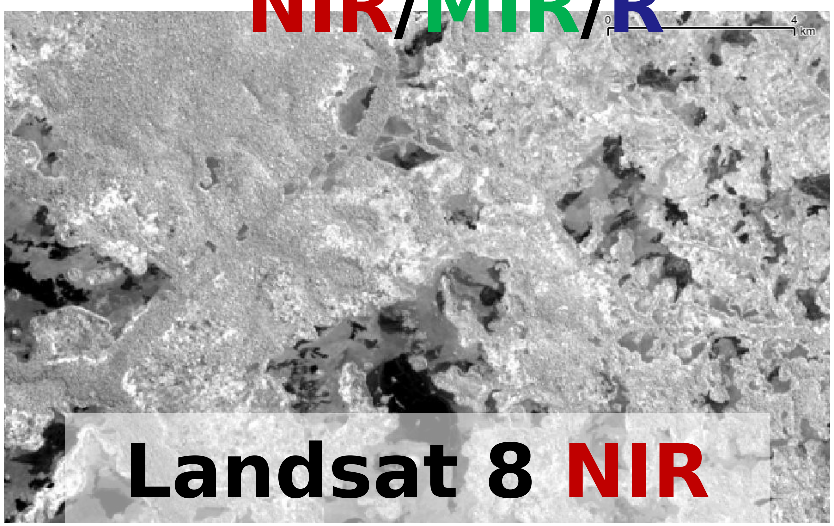


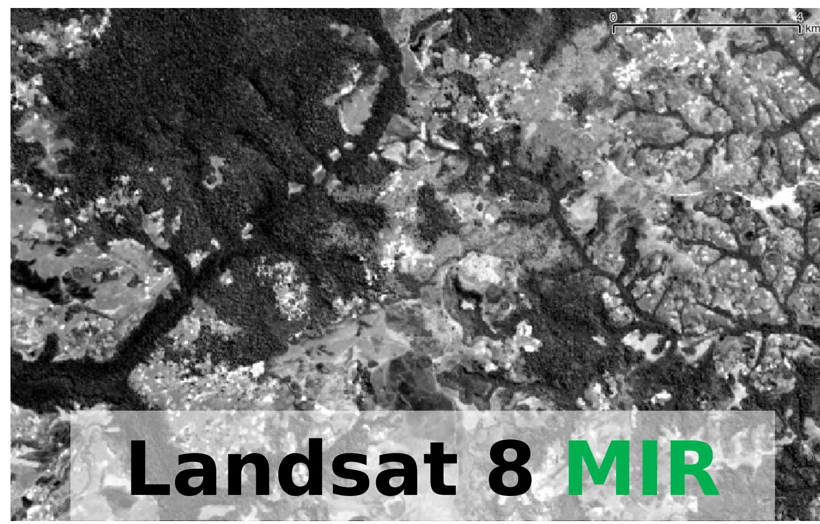
Source: Lillesand *et al.,* 20

Bande spectrale









DISCRIMINATION Broad leaved/ conifers with the InfraRed

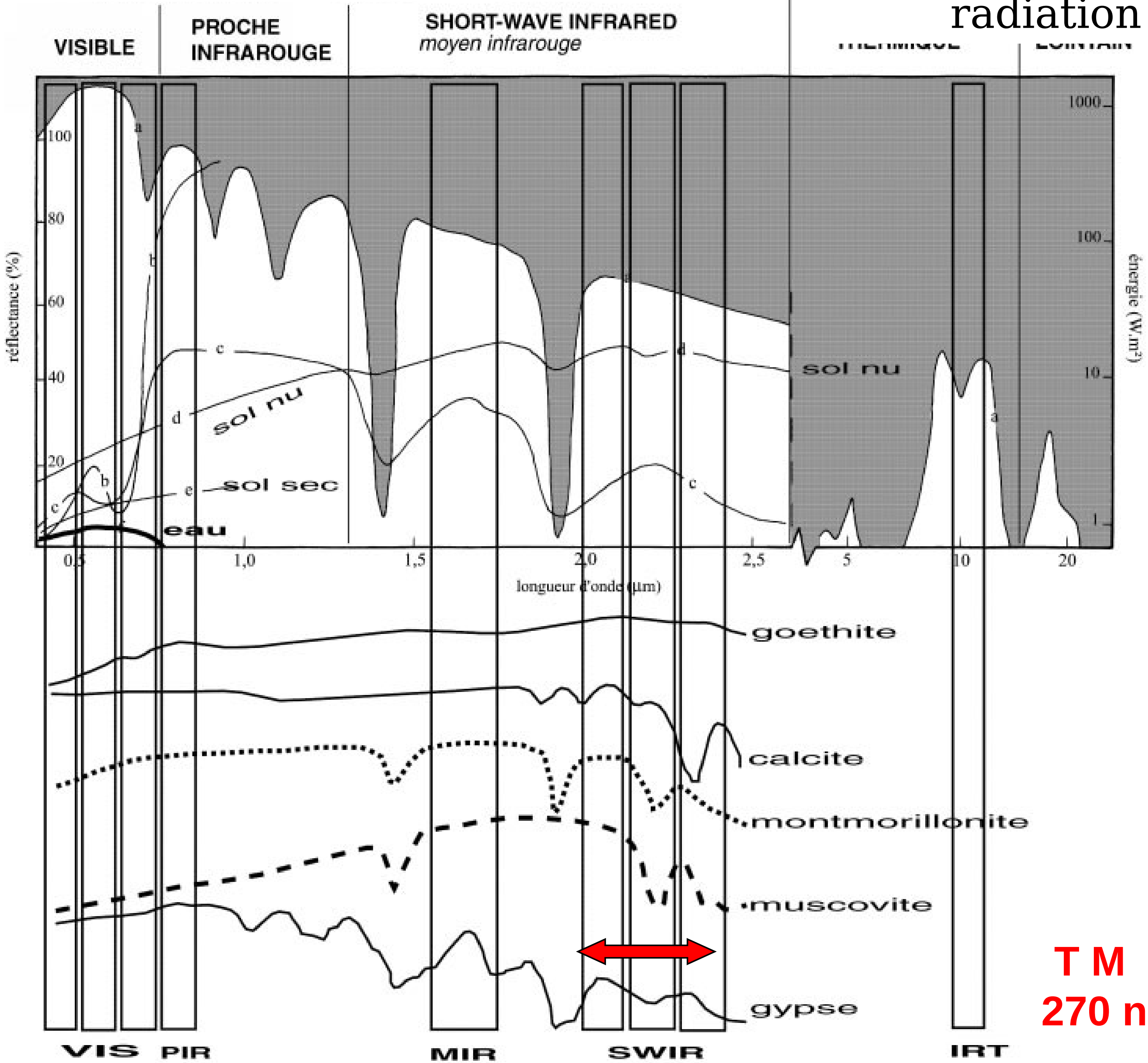
anchromatic channel
(*0.4 – 0.7 µm*)

ear-InfreRed channel
(*0.7-0.9 µm*)

Source: Lillesand *et al.,* 20

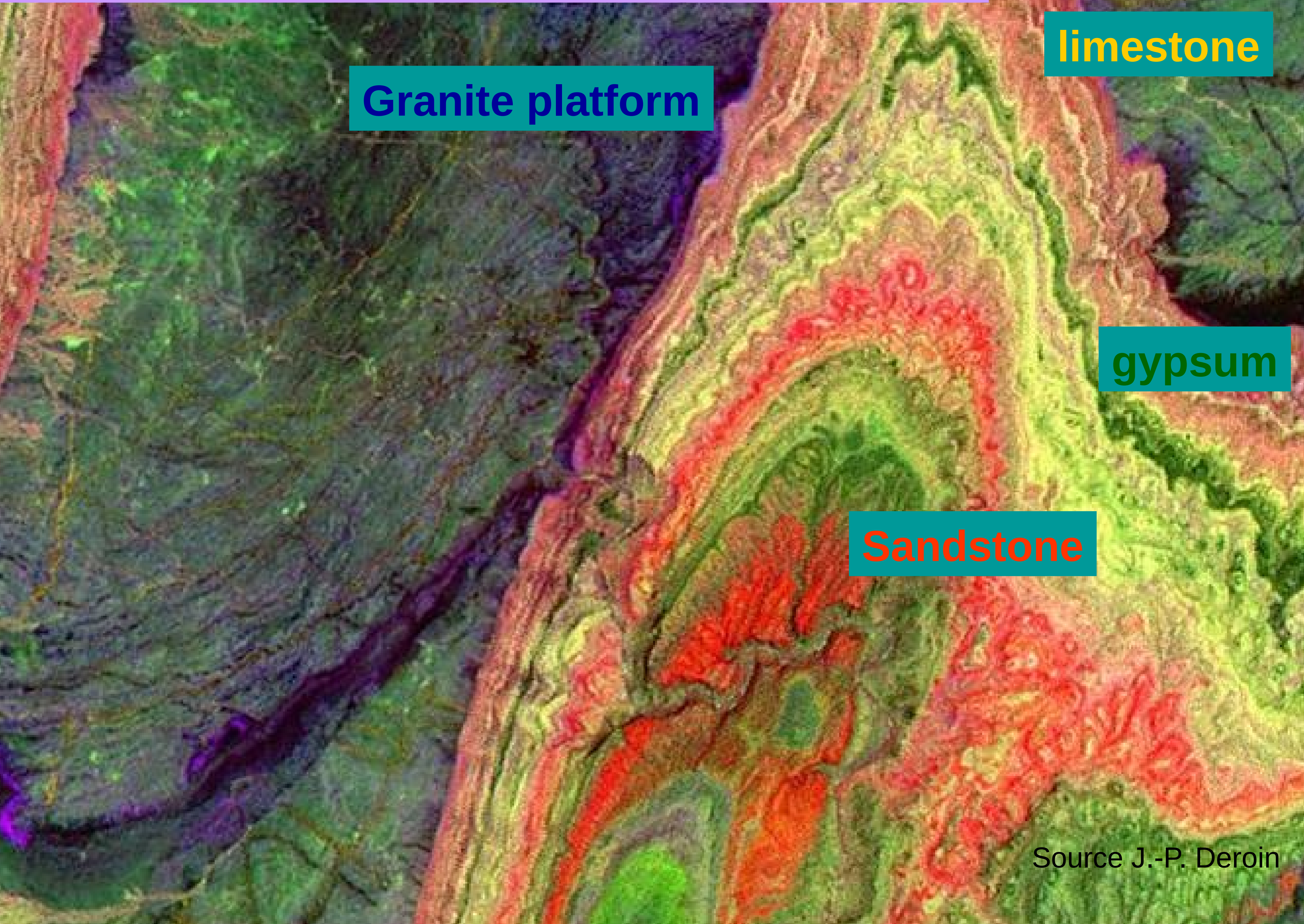
Reflected Solar radiation

Emitted Solar radiation



T M 7
270 nm

ASTER data over Anti-Atlas *(Maroc),* 13 juin 2001



Multispectral : Example of MODIS (36 canaux [µm])

Terre/Nuages – Aérosols

1- 0,620-0,670
2- 0,841-0,876
3- 0,459-0,479
4- 0,545-0,565
5- 1,230-1,250
6- 1,628-1,652
7- 2,105-2,155

Couleur de l'océan – Phytoplankton – Biochimie

8- 0,405-0,420
9- 0,438-0,448
10-0,483-0,493
11-0,526-0,536
12-0,546-0,556
13-0,662-0,672
14-0,673-0,683
15-0,743-0,753
16-0,862-0,877

Vapeur d'eau atmosphérique

17- 0,890-0,920
18- 0,931-0,941
19- 0,915-0,965

Température de surface et des nuages

20- 3,660-3,840
21- 3,929-3,989
22- 3,929-3,989
23- 4,020-4,080

Température atmosphérique

24- 4,433-4,498
25- 4,482-4,529

Vapeur d'eau (cirrus)

26- 1,360-1,390
27- 6,535-6,895
28- 7,175-7,475

29- 8,400-8,700 Nuages
30- 9,580-9,880 Ozone

Température de surface/nuages

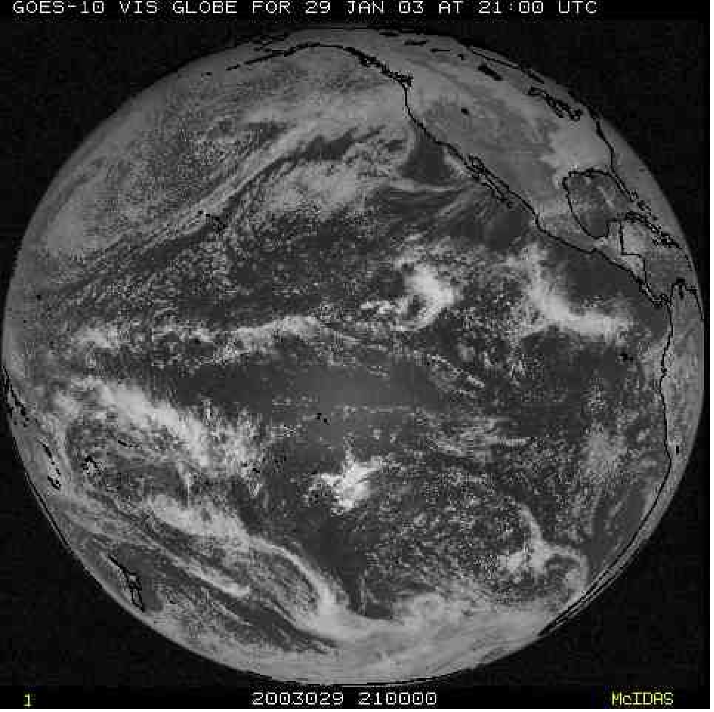
31-10,780-11,280
32-11,770-12,270

Altitude du sommet des nuages

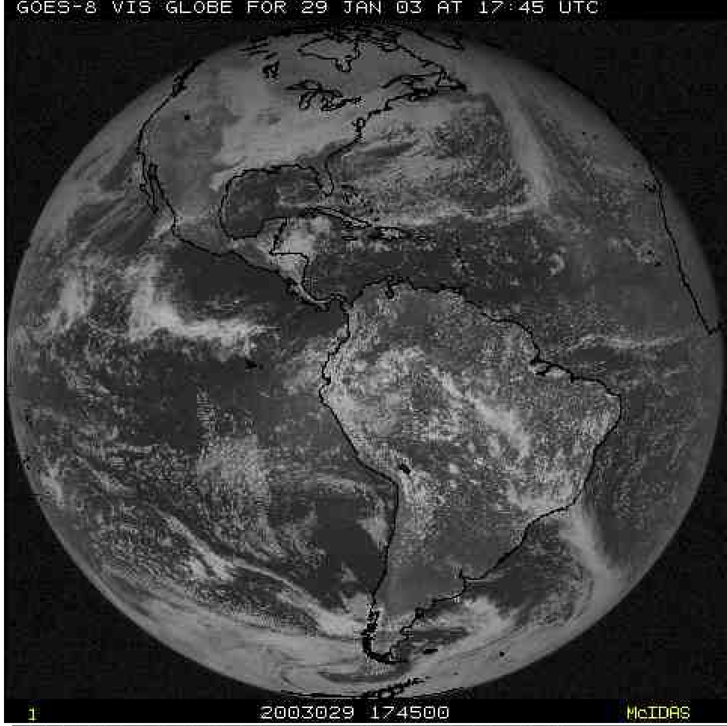
33-13,185-13,485
34-13,485-13,785
35-13,785-14,085
36-14,085-14,385

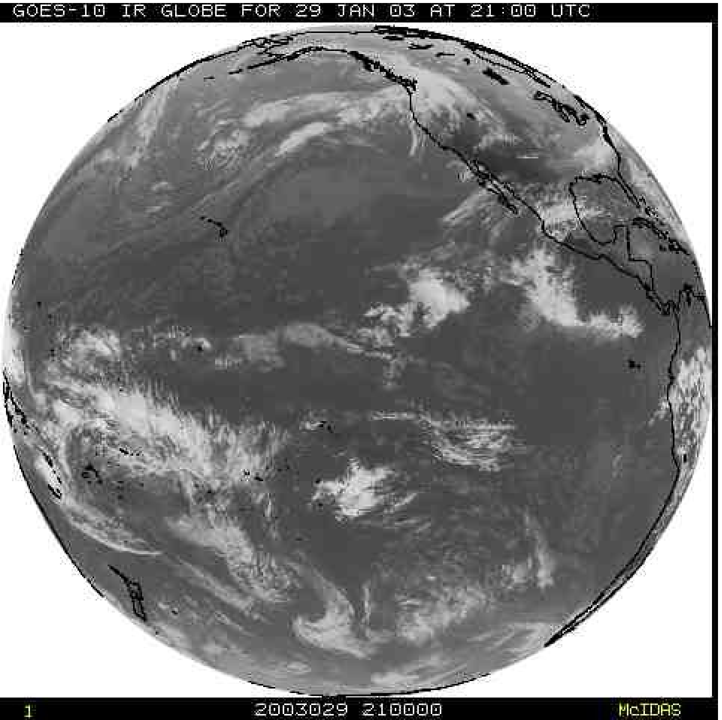
250m **500m** **1000m**

Satellites GOES

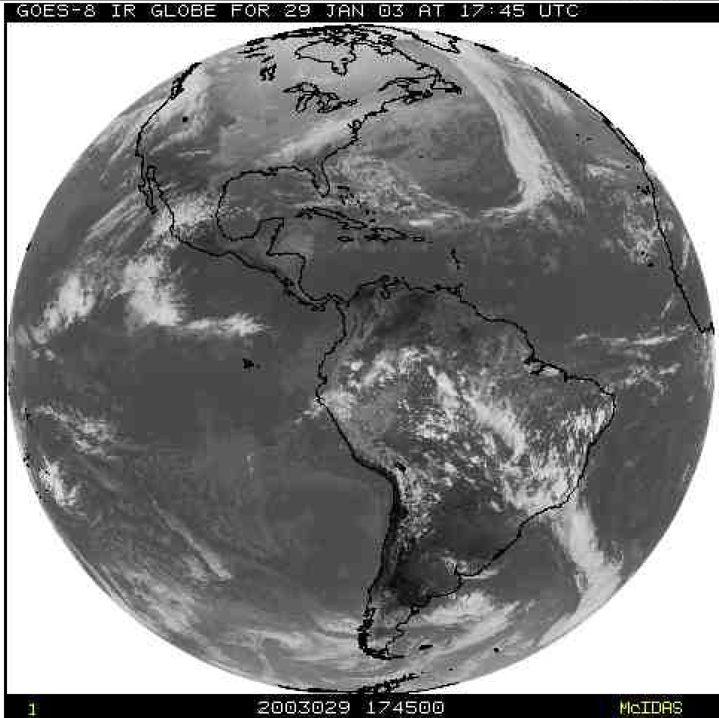


Visible





Infra-Rouge



MSG - 04.décembre.2002