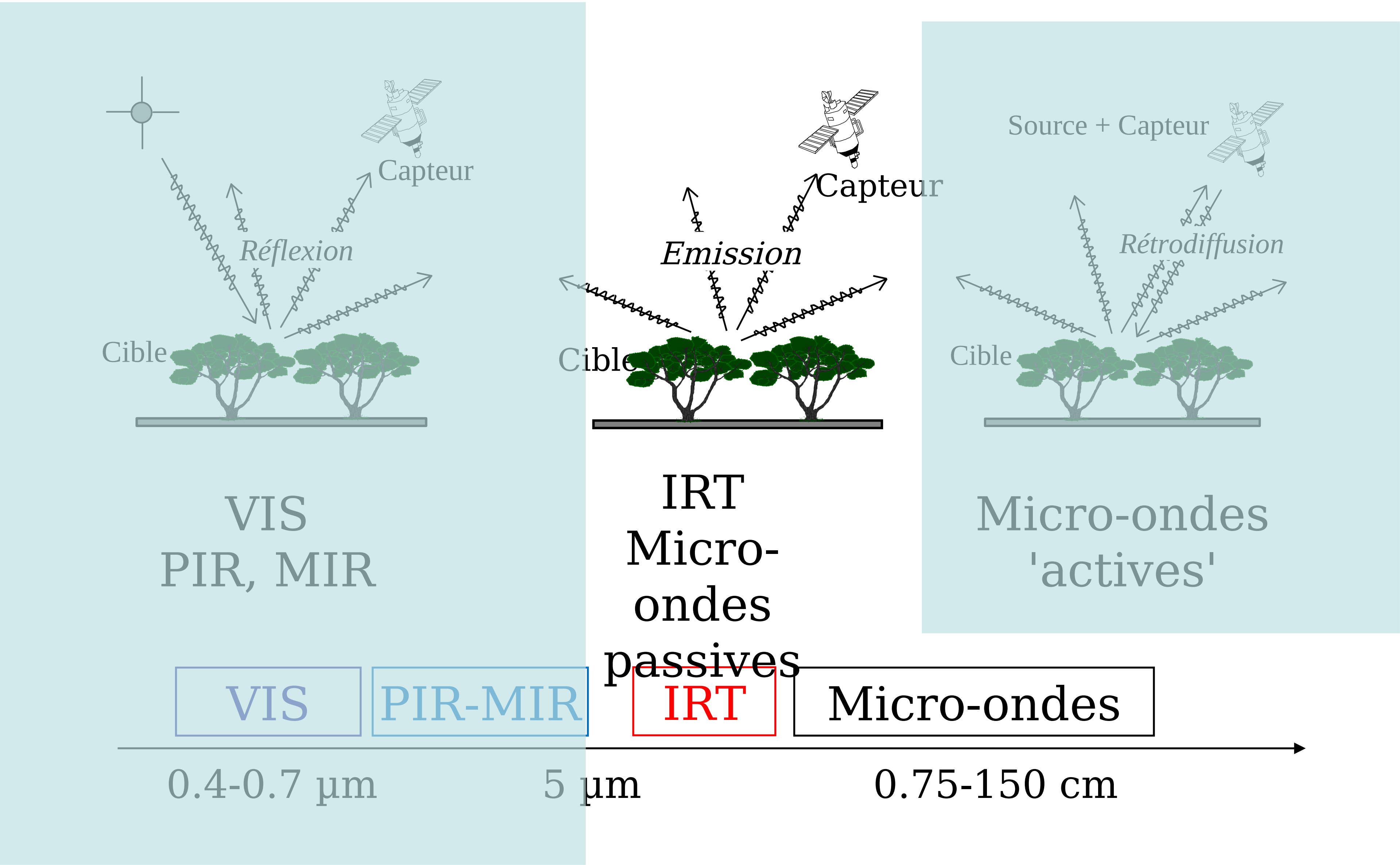
Thermal InfraRed & microwaves
5 μm – 10 m

Modes d'observations



OPTICAL DOMAIN

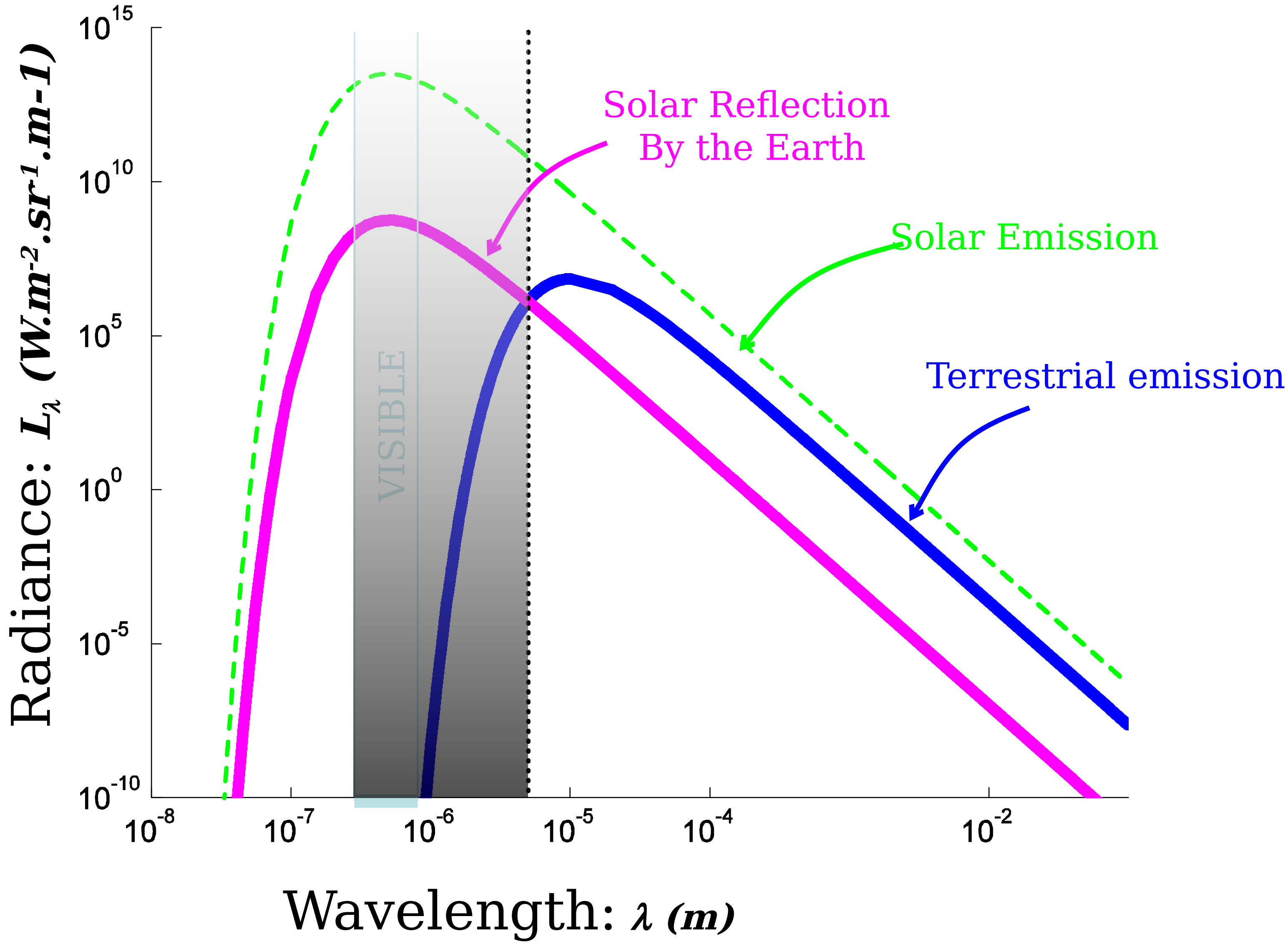


Image globale NOAA-AVHRR

Canal Rouge

1-10 avril 1992

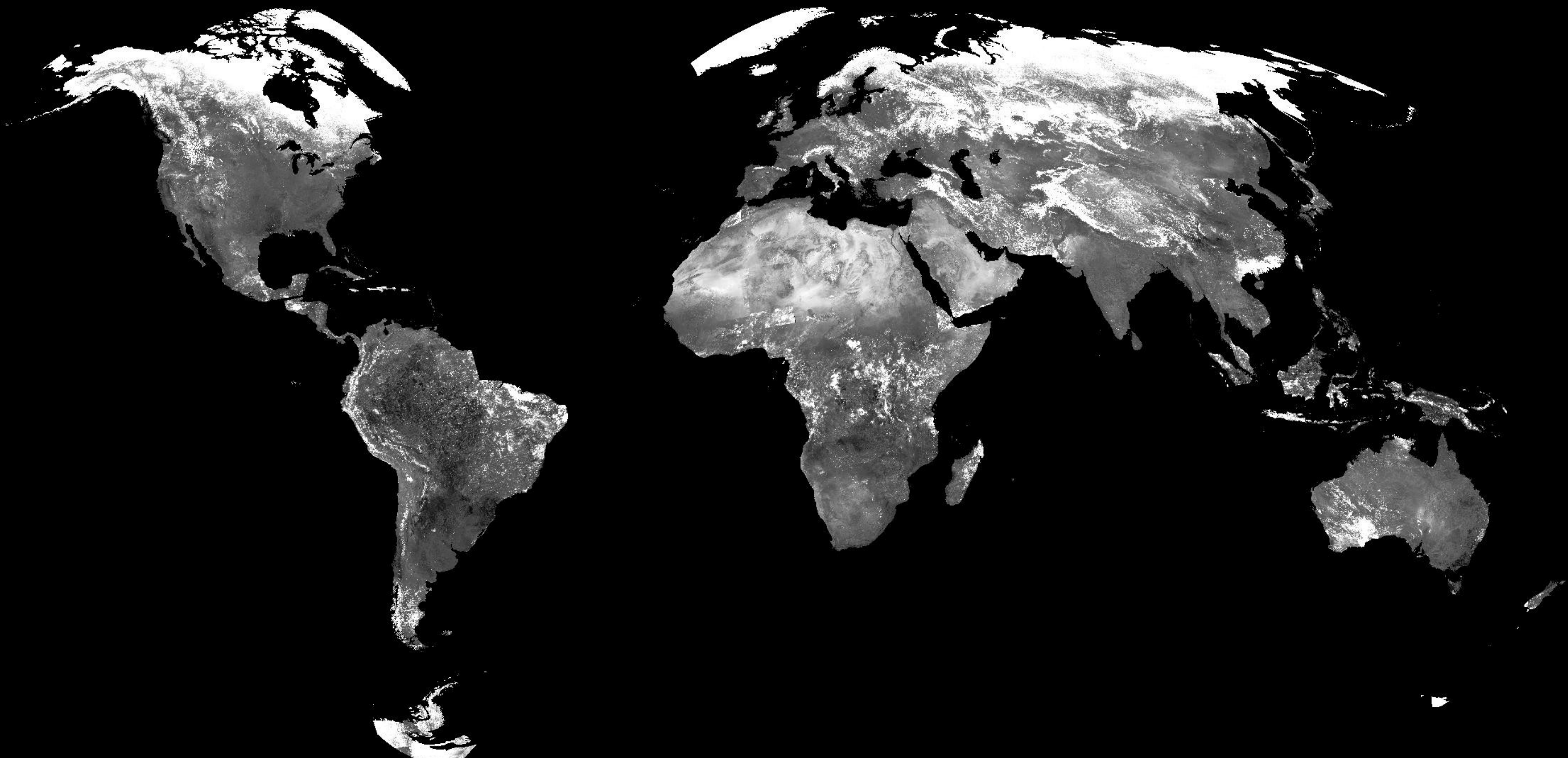


Image globale NOAA-AVHRR

Canal Proche-InfraRouge

1-10 avril 1992

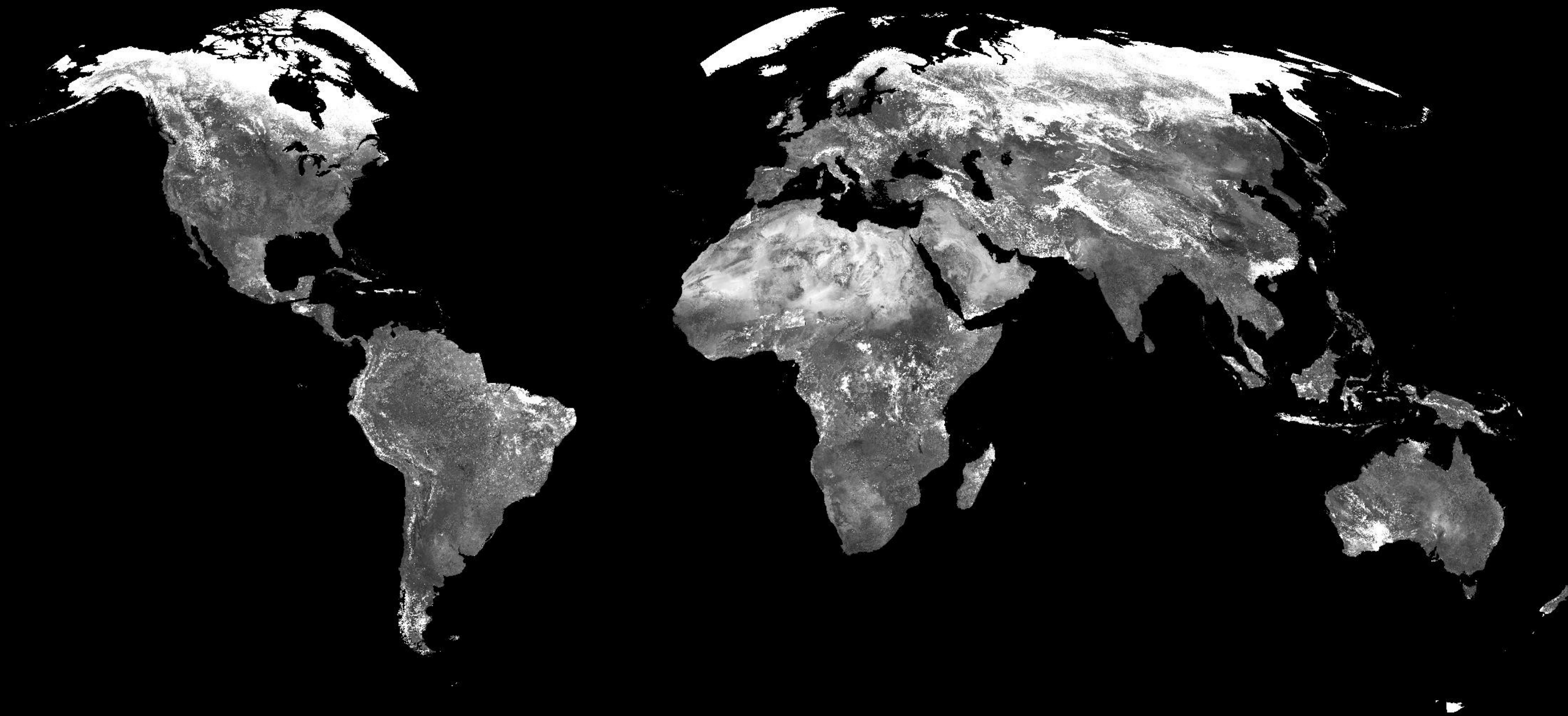
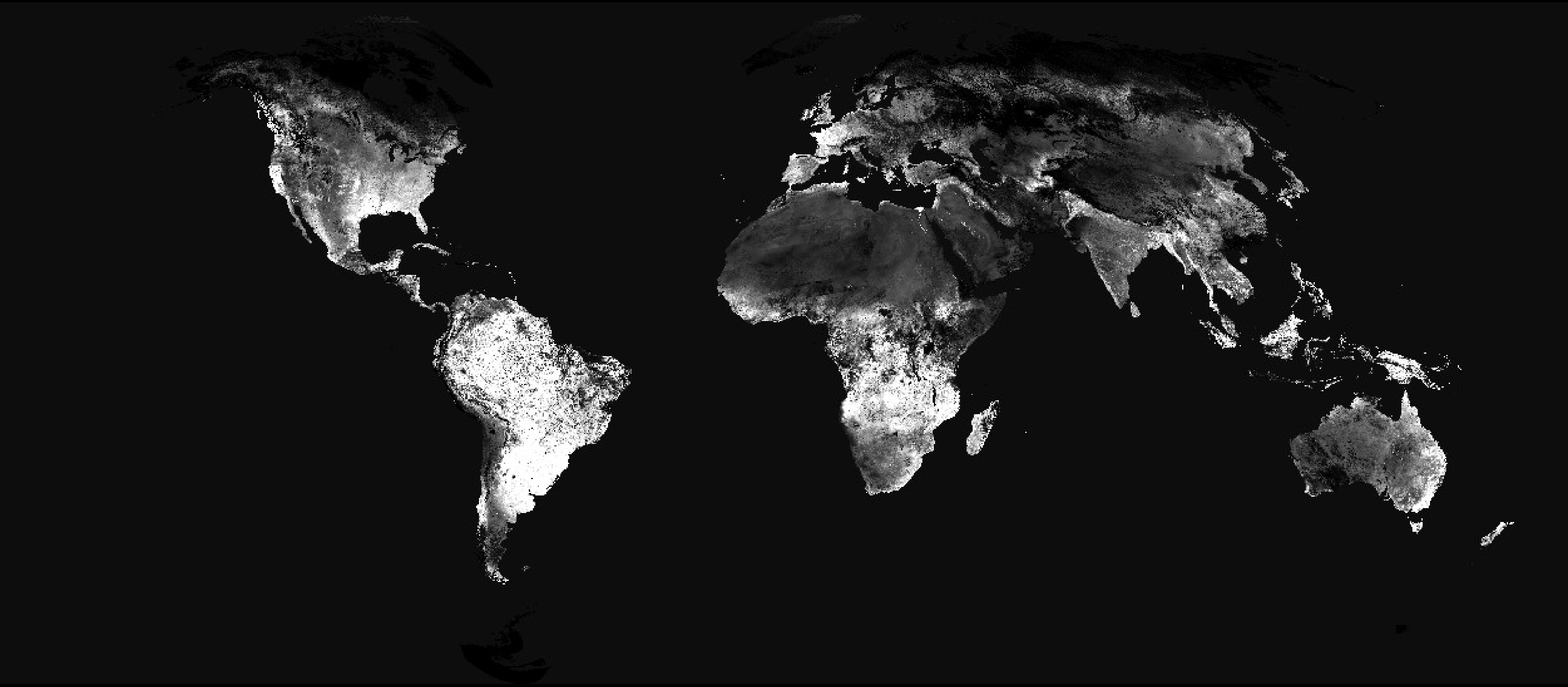


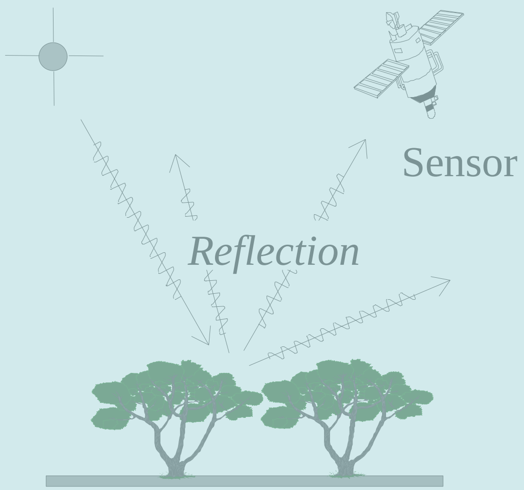
Image globale NOAA-AVHRR

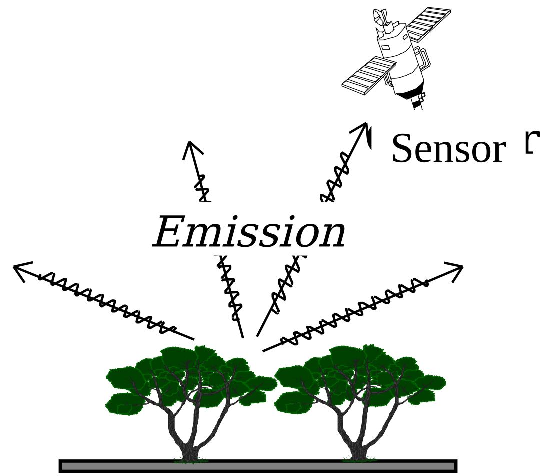
NDVI

1-10 avril 1992



Observation Modes





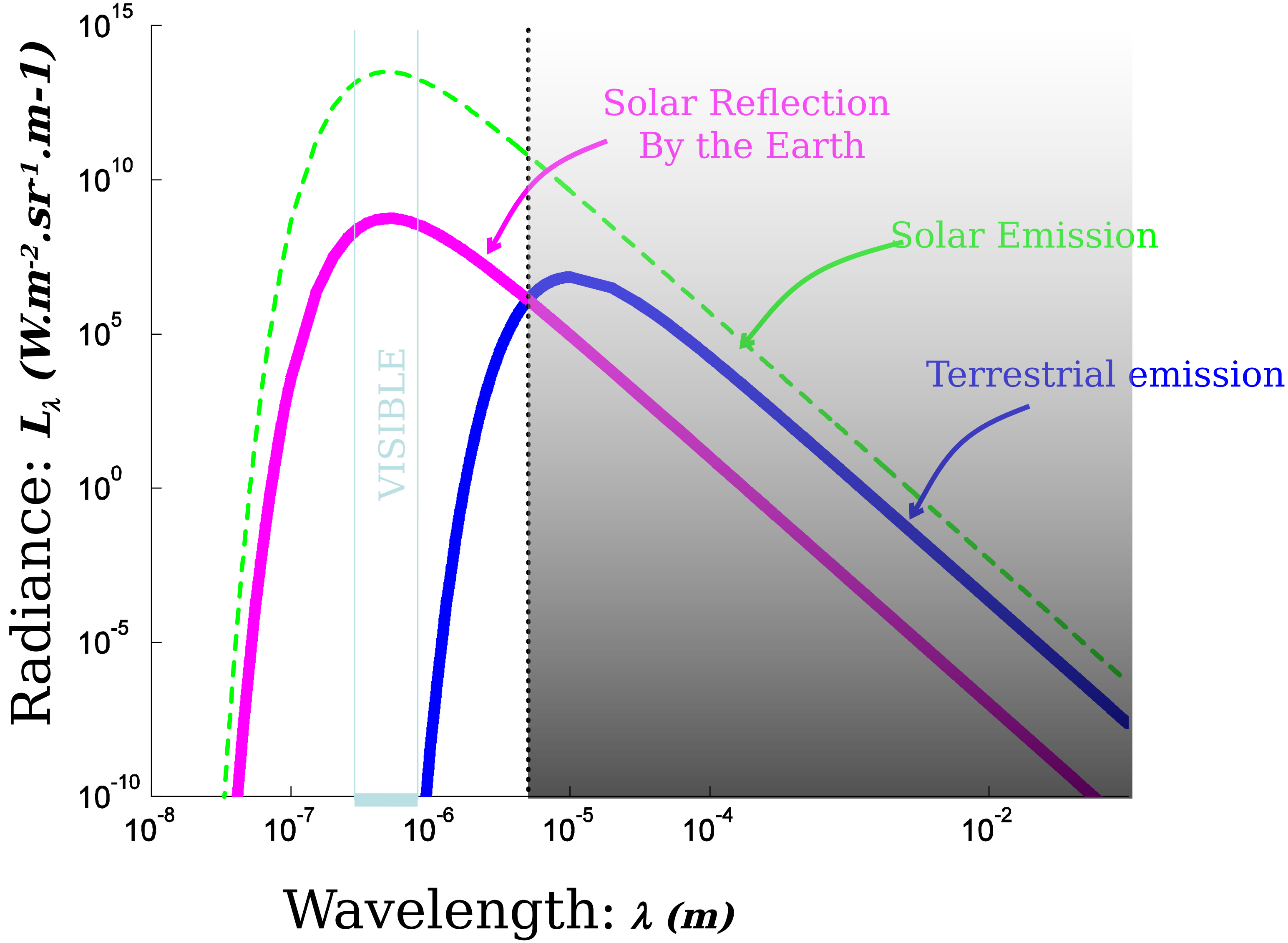
VIS
NIR, MIR

TIR
Passive
microwaves

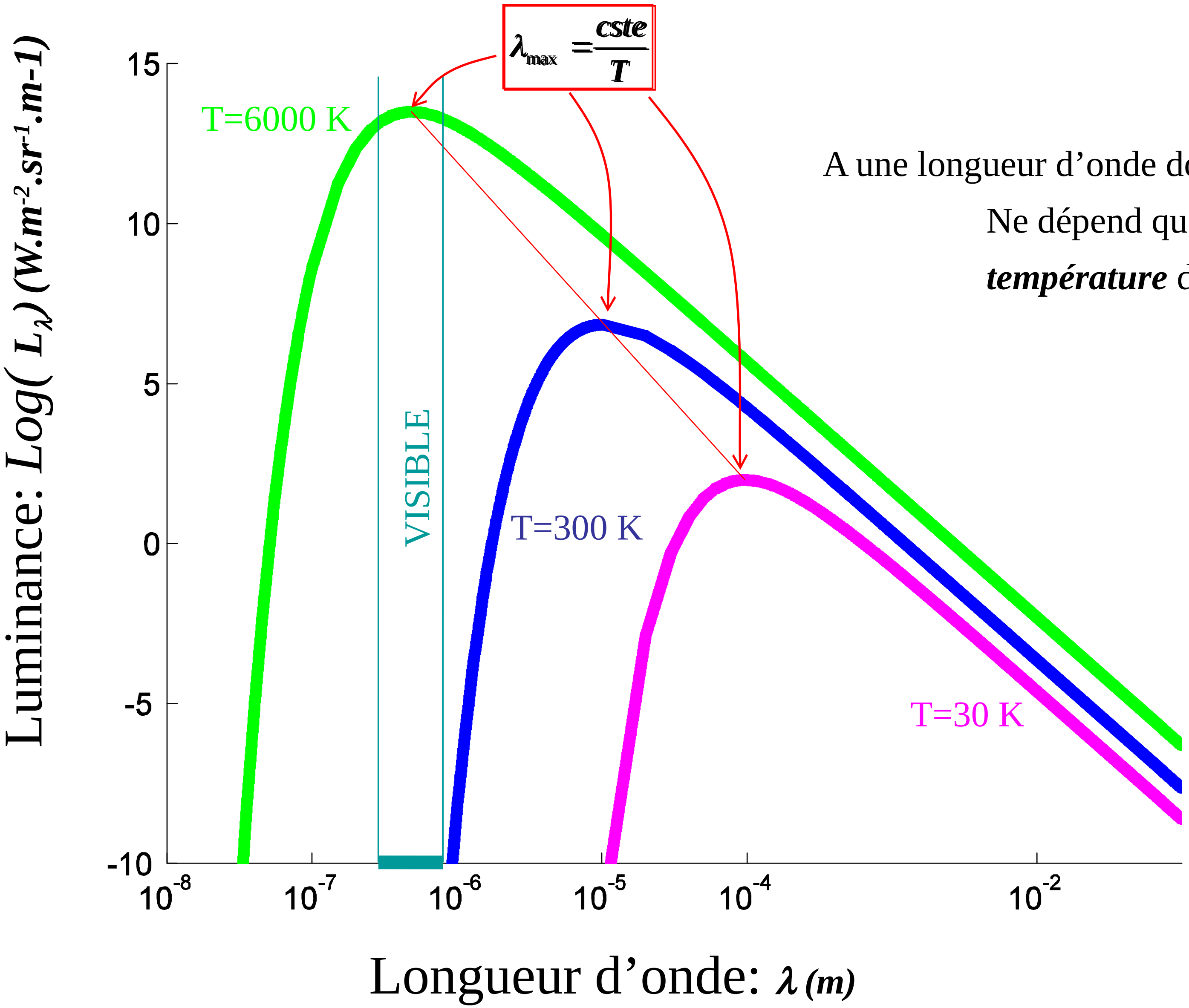
VIS | NIR-MIR | TIR | Microwaves

0.4-0.7 µm — 5 µm — 0.75-150 cm

Thermal InfraRed - Microwaves



Le Rayonnement du corps noir

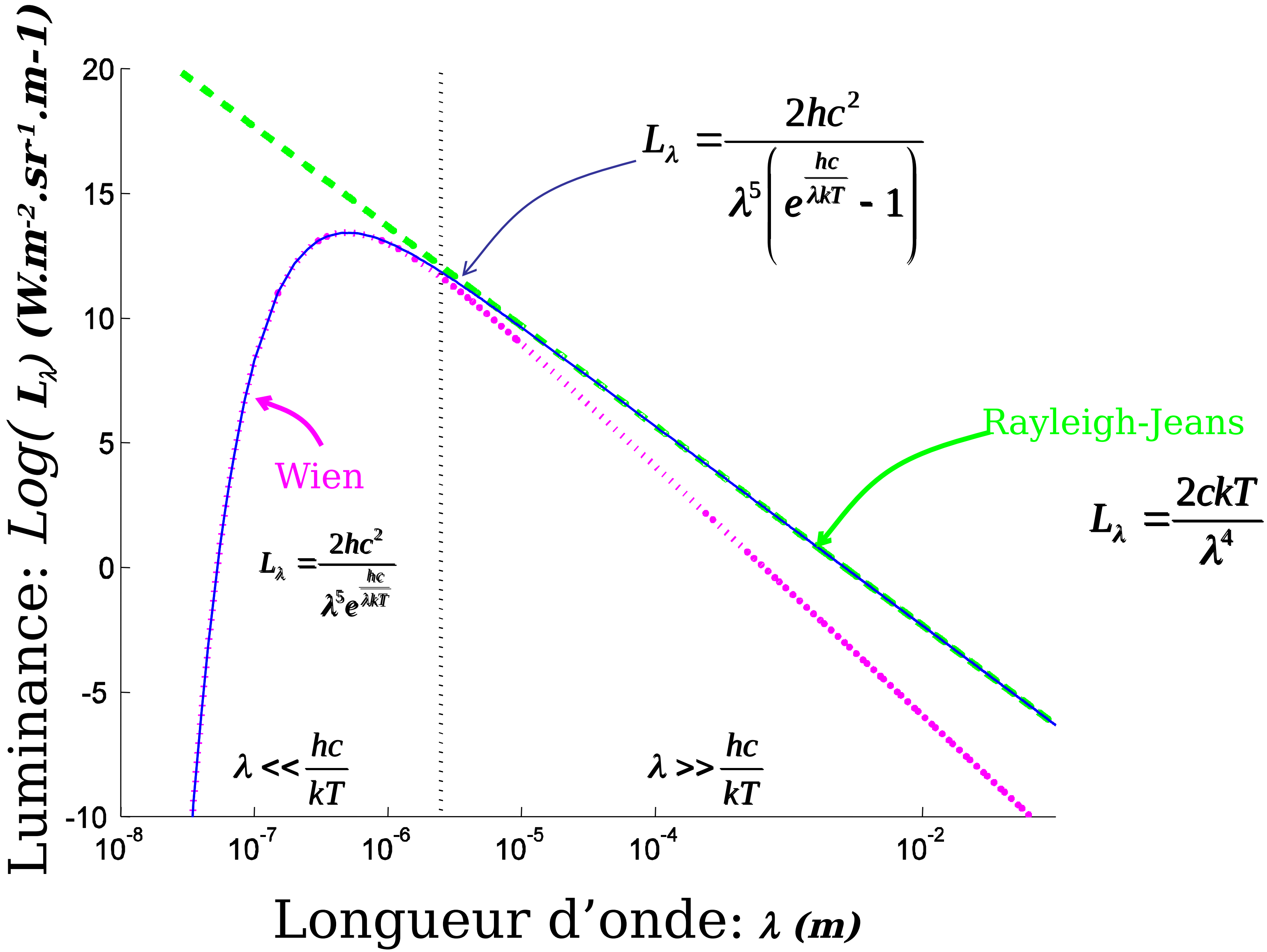


A une longueur d'onde donnée:

Ne dépend que de la

température du corps étudié

Rayonnement du corps noir: Approximations de Wien et de Rayleigh-Jeans



mal InfraRed+ Passive microwaves(5 μm – 10 m)

(emitted radiation by the observed su

Long wavelenghts: $L_\lambda = \frac{2ckT}{\lambda^4}$

Radiance of the studied body

Radiance of the black body having the same physical temp.

ck body (ideal) ≠ Gray Body (natural) ⇒ *Emissivity:* $L_\lambda = \varepsilon(\lambda)\, L_{\lambda\, cn}$

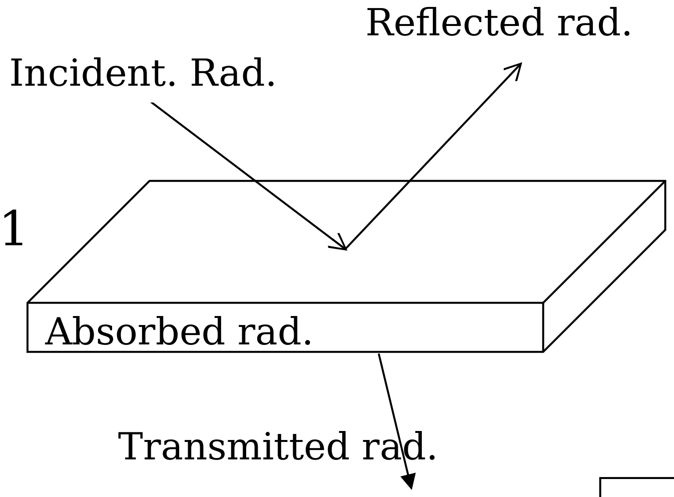
$$0 \leq \varepsilon(\lambda) \leq 1$$

htness Temperature T_b: *Physical temperature of the black body that would emit the same radiation than the gray bod*

$$\frac{2ckT_b}{\lambda^4} = \varepsilon \frac{2ckT}{\lambda^4} \quad \Rightarrow \quad \boxed{T_b = \varepsilon\, T}$$

Energy conservation

$$0 \leq \begin{matrix}\rho_\lambda \\ \alpha_\lambda \\ \tau_\lambda\end{matrix} \leq 1$$



reflectance $\rho_\lambda = \dfrac{\text{reflected radiation}}{\text{incident radiation}}$

absorptance $\alpha_\lambda = \dfrac{\text{absorbed radiation}}{\text{incident radiation}}$

transmittance $\tau_\lambda = \dfrac{\text{transmitted radiation}}{\text{emitted radiation}}$

$$\boxed{\rho_\lambda + \tau_\lambda + \alpha_\lambda = 1}$$

Particular cases:

Black body: $\rho = \tau = 0$ $\alpha = 1$

Opaque body: $\tau = 0$ $\alpha + \rho = 1$

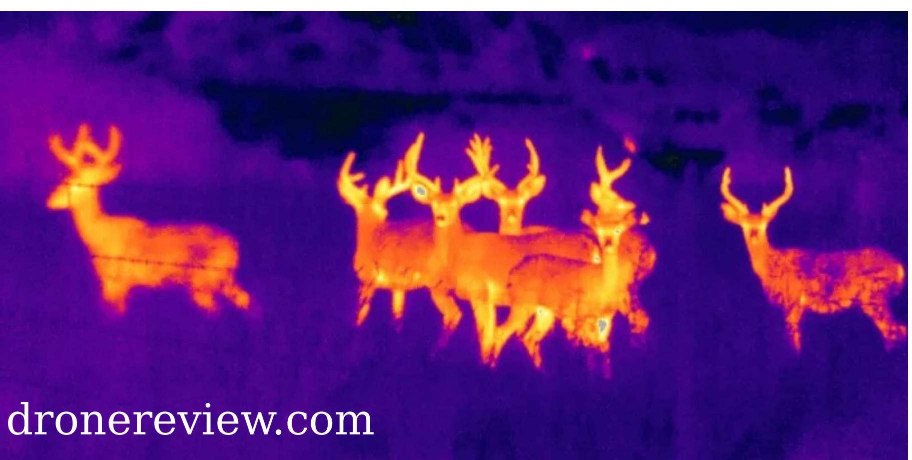
Kirchoff law:
(équilibre thermodynamique)

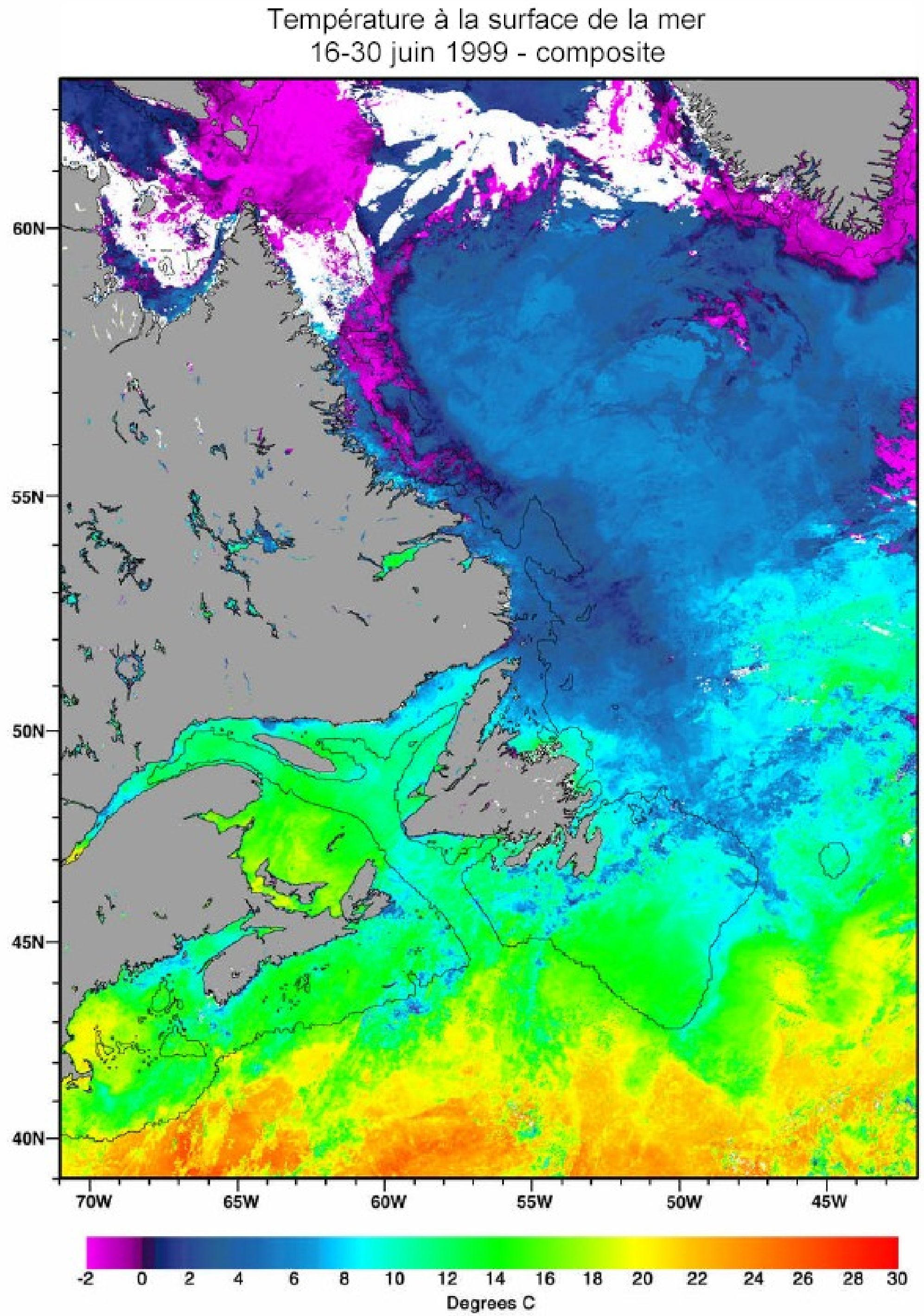
$\boxed{\alpha = \varepsilon}$ $\Rightarrow$

Black body: $\varepsilon = \alpha = 1$

Opaque body: $\varepsilon + \rho = 1$

Emited radiation in Thermal InfraRed $\neq$ **(amplified) reflected Radiation in Visible**



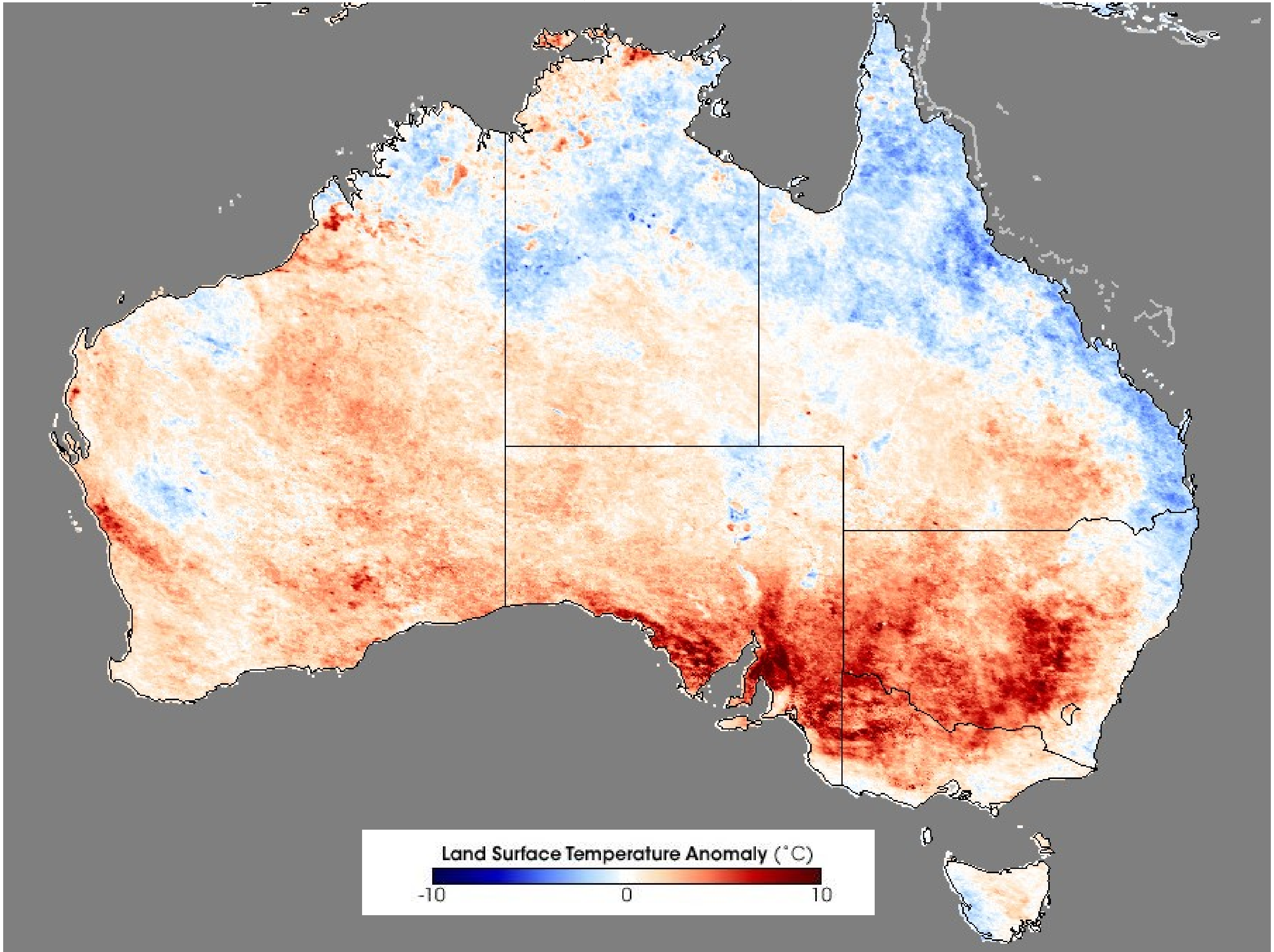


SeaWIFS
Sea Surface Temperature
estimated from
InfraRed channels

MODIS

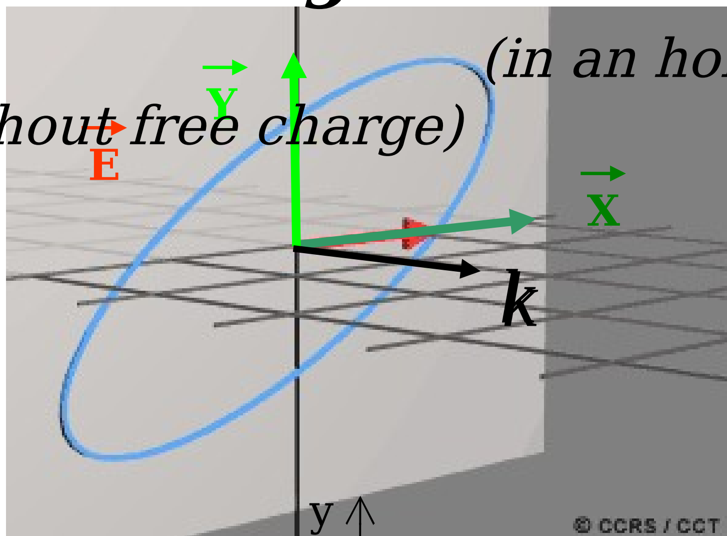
Monthly surface Temperature Anomaly: September 2006

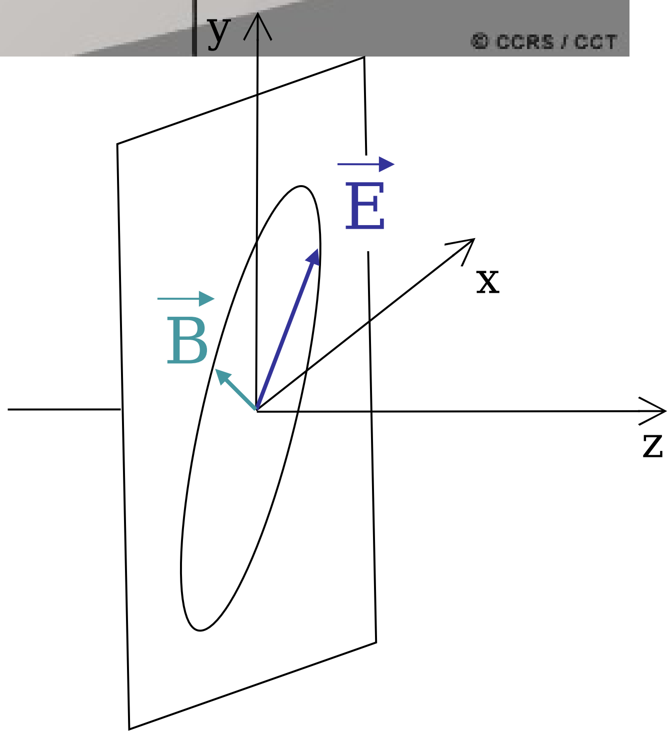
(*vs* 2000-2005)



Polarization *of a Electromagnetic wave*

(in an homogeneous medium without free charge)





$$E = E_0 \cos(\omega t - kz)$$

frequency: f

fréq. ang.: $\omega = 2\pi f$

Wave number: $k = \frac{2\pi f}{c}$

Phase speed: $v = \frac{\omega}{k} = \frac{1}{\sqrt{\varepsilon \mu}} = \frac{c}{\sqrt{\varepsilon_r \mu_r}}$

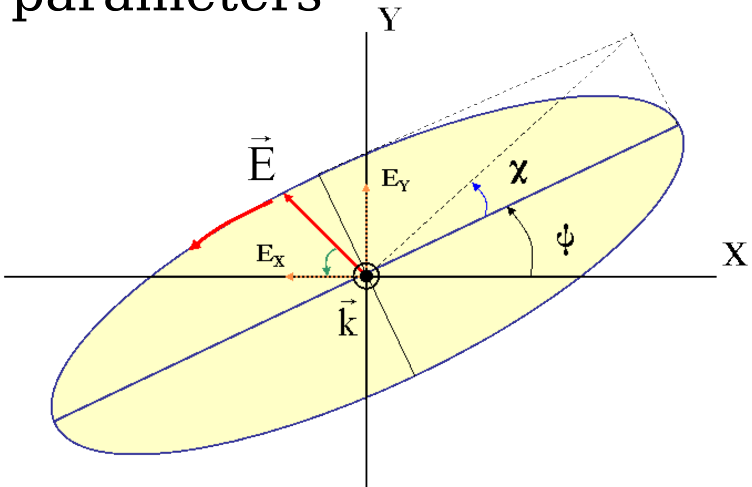
Relative permitivity: $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$

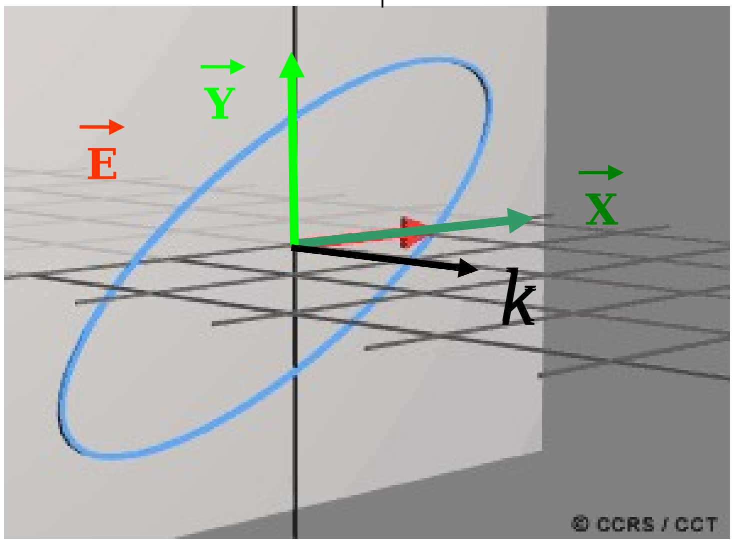
Relative permeability: $\mu_r = \frac{\mu}{\mu_0} \approx 1$

Polarization *of a Electromagnetic wave*

Ellipse of polarization

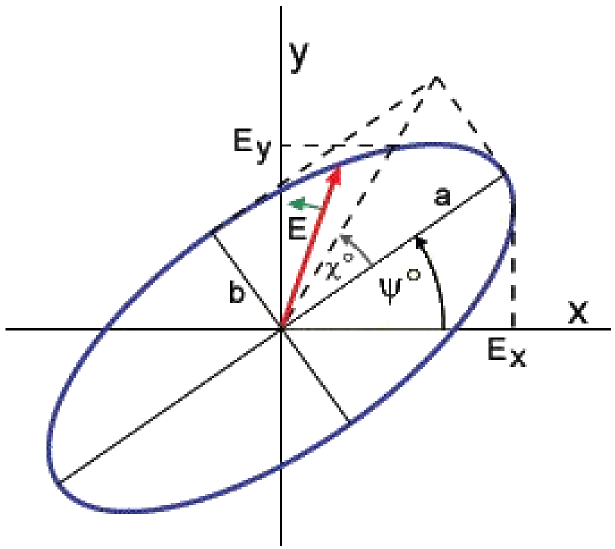
C*oherent* sensor (amplitudes + phase of field E) : 3 parameters

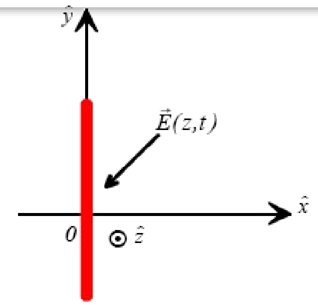




- **Orientation Ψ**
- **Ellipticity χ**
  - linear: χ = 0
  - Circular:
    - Left χ = 45°
    - Right χ = -45°
- **Amplitude**

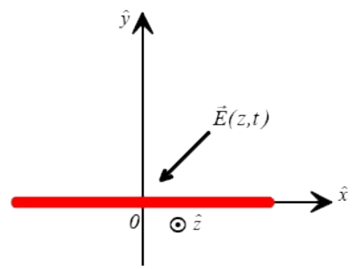
POLARISATIONS





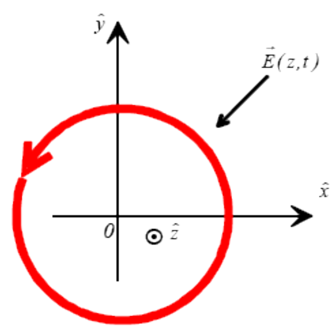
Polarisation Verticale : *V*

$\chi = 0, \ \ \psi = \Pi/2$



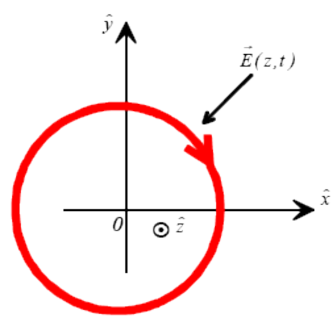
Polarisation Horizontale : *H*

$\chi = 0, \ \ \psi = 0$



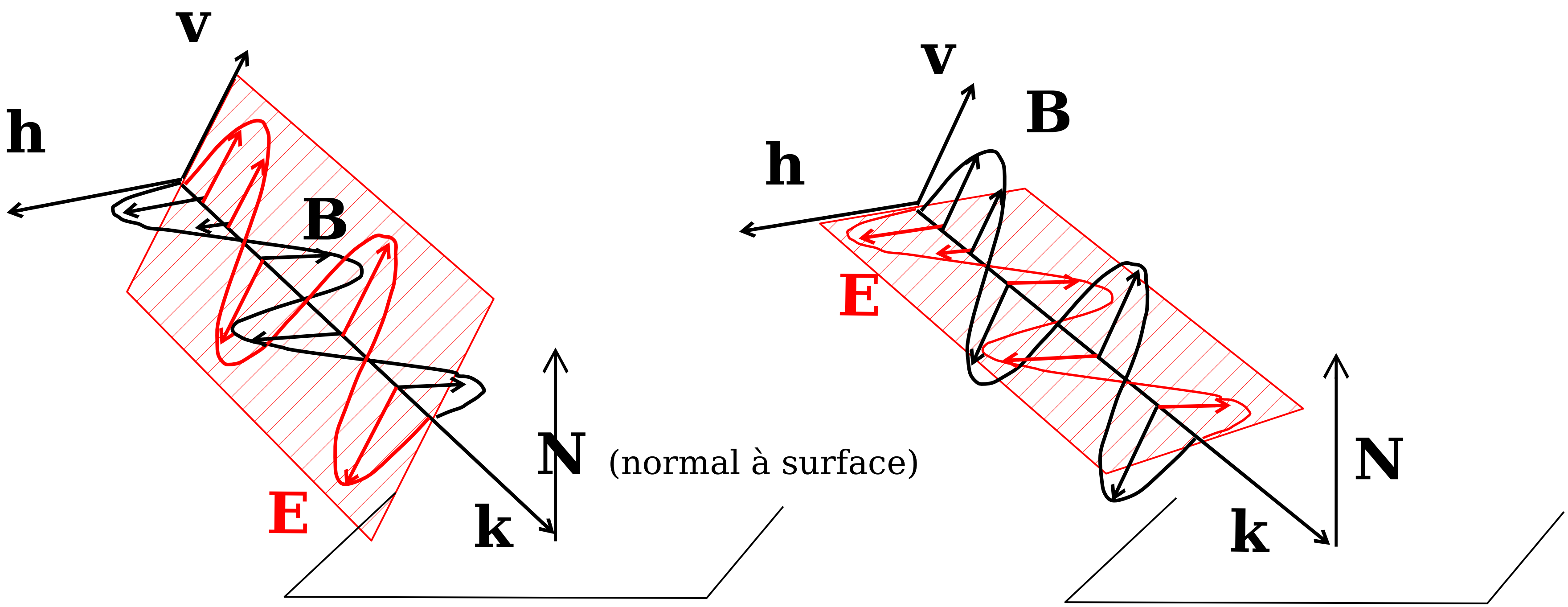
Polarisation Circulaire Droite : *D*

$\chi = -\pi/4$



Polarisation Circulaire Gauche : *G*

$\chi = \pi/4$

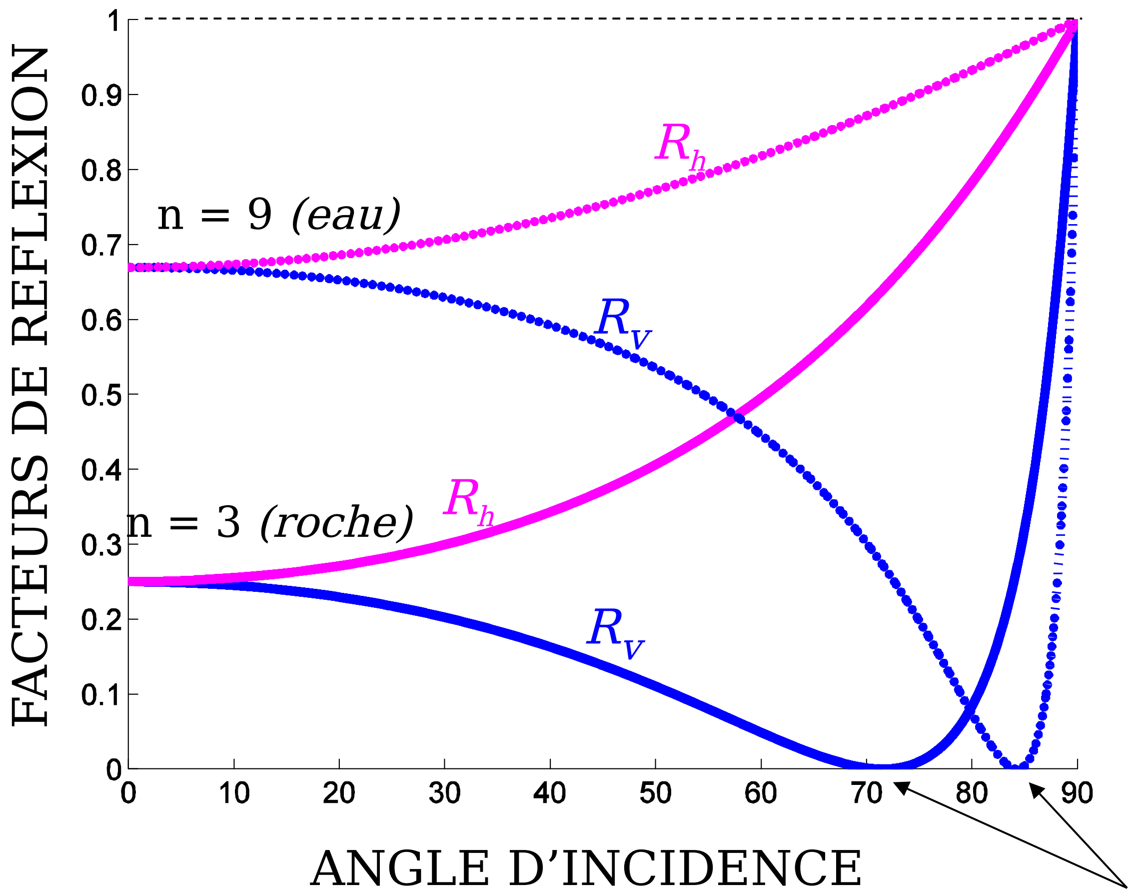


(**k**, **N**): plan d 'incidence

Polarisation verticale
parallèle
TM (transverse magnétique)

Polarisation horizontale
orthogonale
TE (transverse électrique)

Facteurs de réflexion $R = |r|^2$



Angles de Brewster

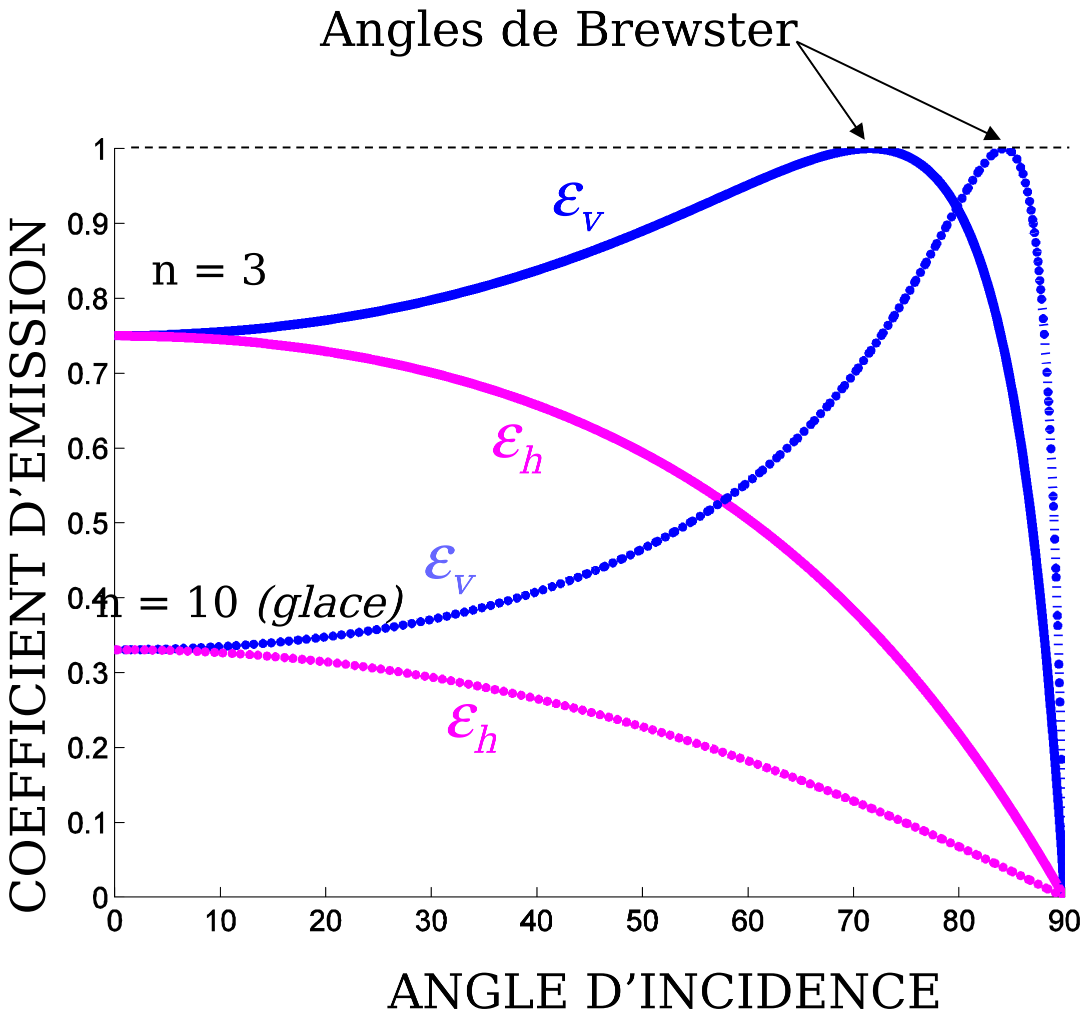
$$E_r = r E_i$$

$$r_v = \frac{\sqrt{\varepsilon_r - \sin^2\theta_1} - \varepsilon_r \cos\theta_1}{\sqrt{\varepsilon_r - \sin^2\theta_1} + \varepsilon_r \cos\theta_1}$$

$$r_h = \frac{\cos\theta_1 - \sqrt{\varepsilon_r - \sin^2\theta_1}}{\cos\theta_1 + \sqrt{\varepsilon_r - \sin^2\theta_1}}$$

Indice de réfraction: $n = \sqrt{\varepsilon_r}$

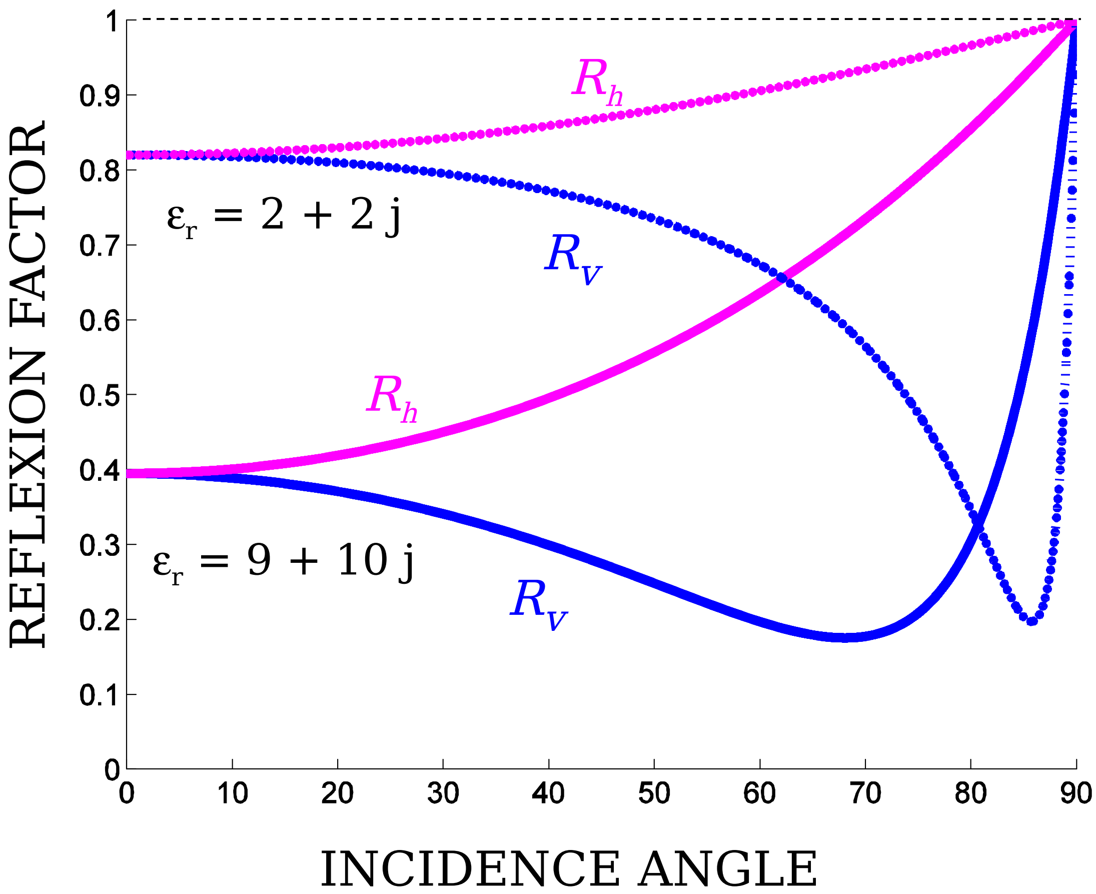
Émissivité pour une surface lisse



$$\mathcal{E} = 1 - R$$

Reflexion factor (energy): $R = |r|^2$

If dispersive medium



$$E_r = r E_i$$

$$r_v = \frac{\sqrt{\varepsilon_r - \sin^2\theta_1} - \varepsilon_r \cos\theta_1}{\sqrt{\varepsilon_r - \sin^2\theta_1} + \varepsilon_r \cos\theta_1}$$

$$r_h = \frac{\cos\theta_1 - \sqrt{\varepsilon_r - \sin^2\theta_1}}{\cos\theta_1 + \sqrt{\varepsilon_r - \sin^2\theta_1}}$$

Refractive index: $n = \sqrt{\varepsilon_r}$

SSM/I sensor Characteristics

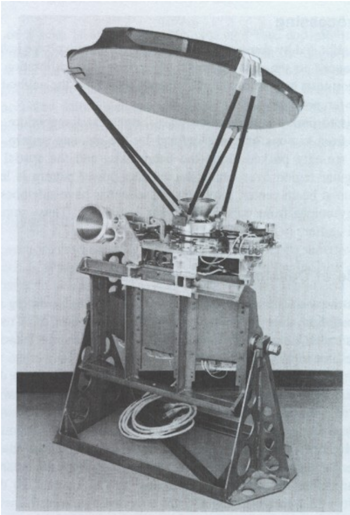
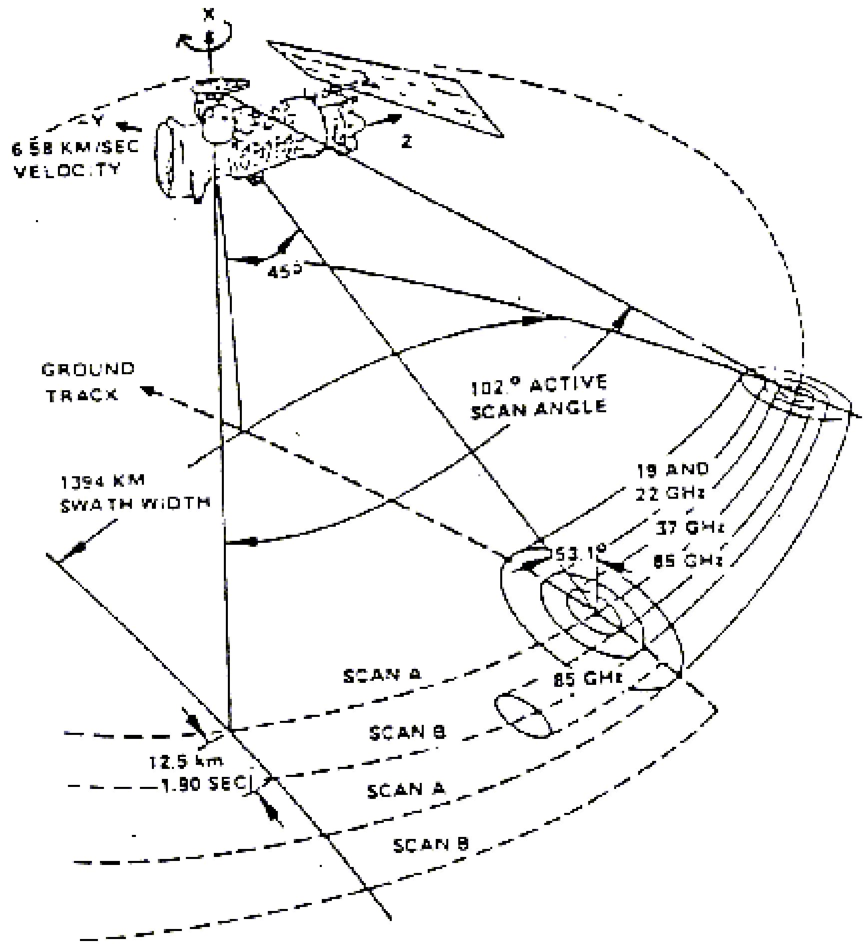


Figure 5-10. SMMR instrument in its handling fixture.



Central Frequency Pol. (GHz)	**19.35**	**22.24**	**37.0**	**85.5**
Radiometric Pol. (V/H) **(*)**	V, H	V	V, H	V, H
Thermal resolution (K)	0.8	0.8	0.6	1.1
Integrated FOV (Km)	70x45	60x40	38 x 30	16x14
Spatial sampling (Km)	25	25	25	12.5
Scan angle			102.4 °	
Sweep periodicity			1.9s	
Ground incidence			53.1°	
Swath width			1394 Km	
Antenna diameter			65 cm	
Weight			120 Kg	
Power			70 W	

Image globale NOAA-AVHRR
Near InfraRed band
1-10 avril 1992

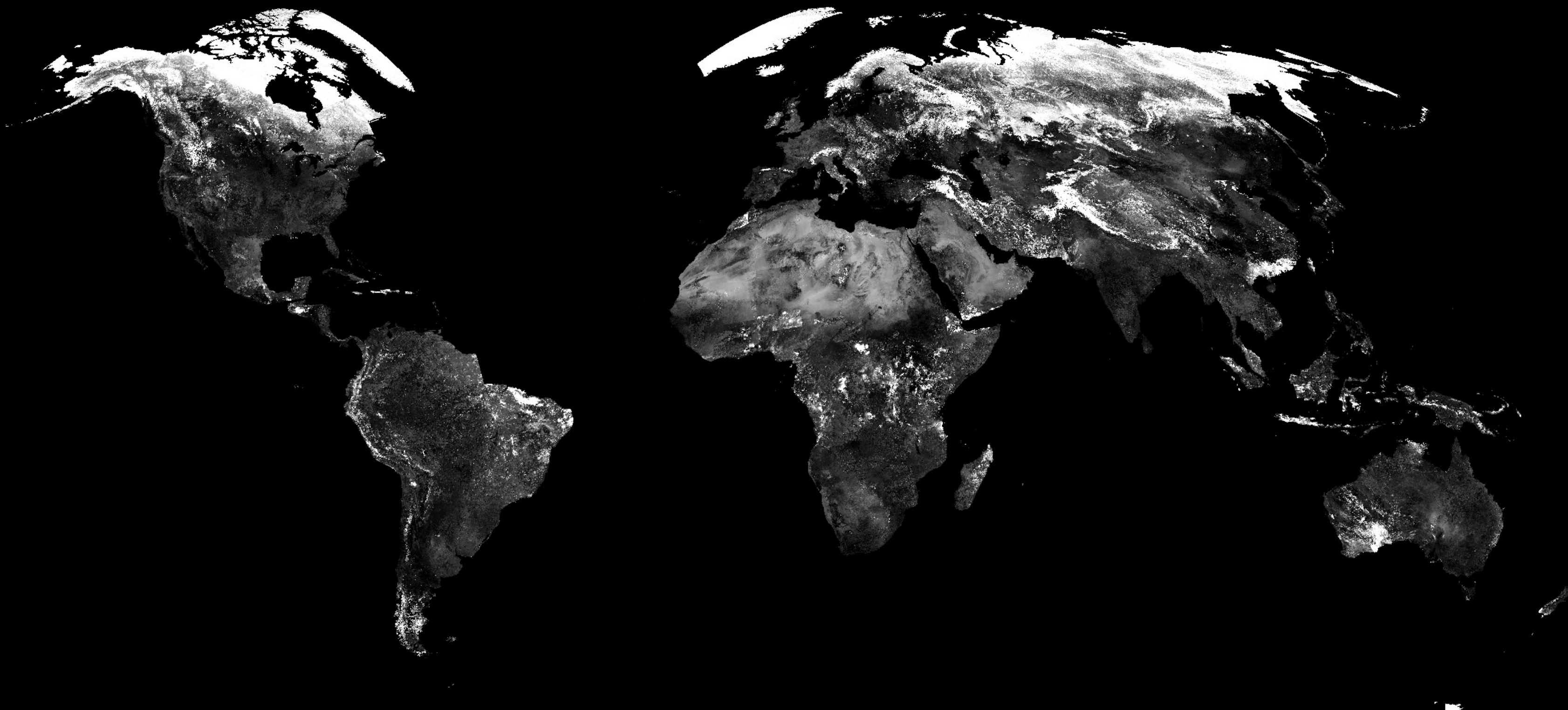


Image globale NOAA-AVHRR
Thermal InfraRed band(12 μm)
1-10 avril 1992

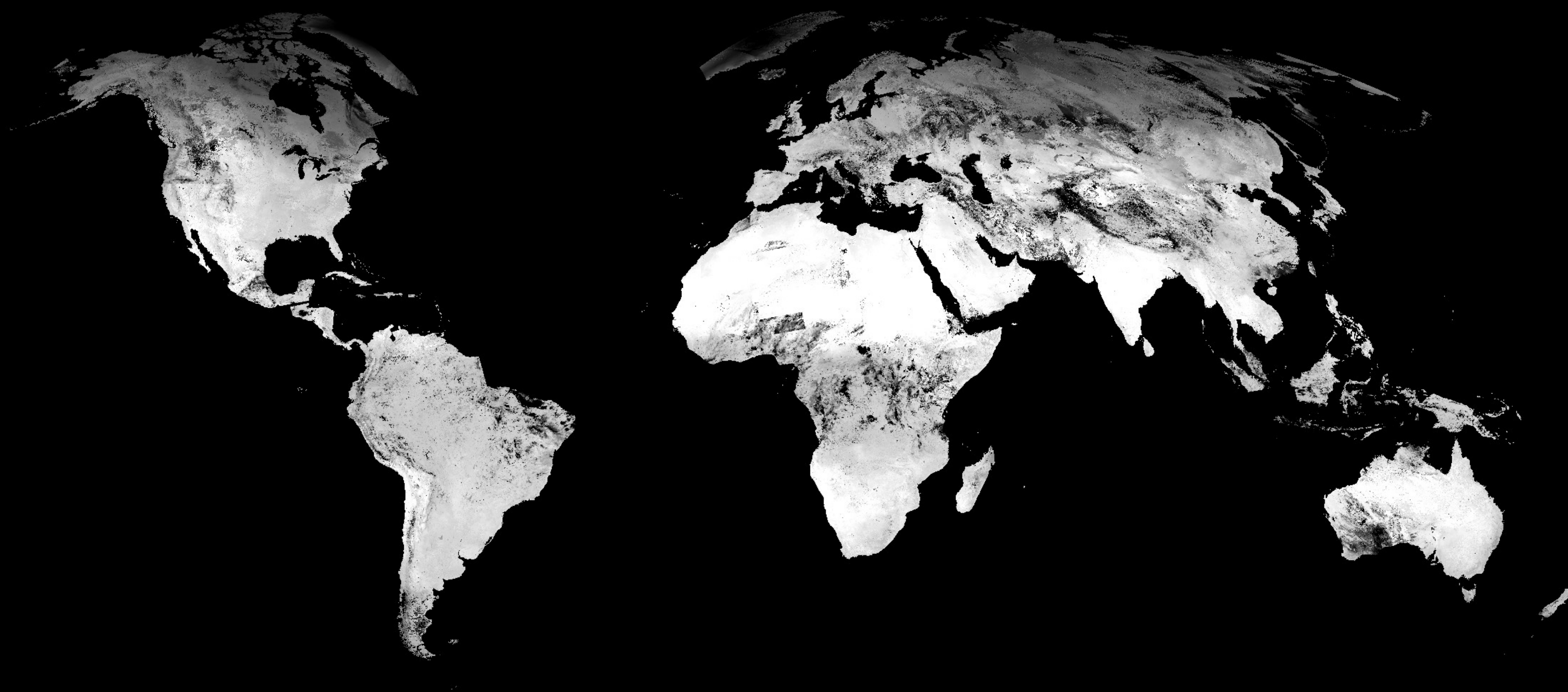
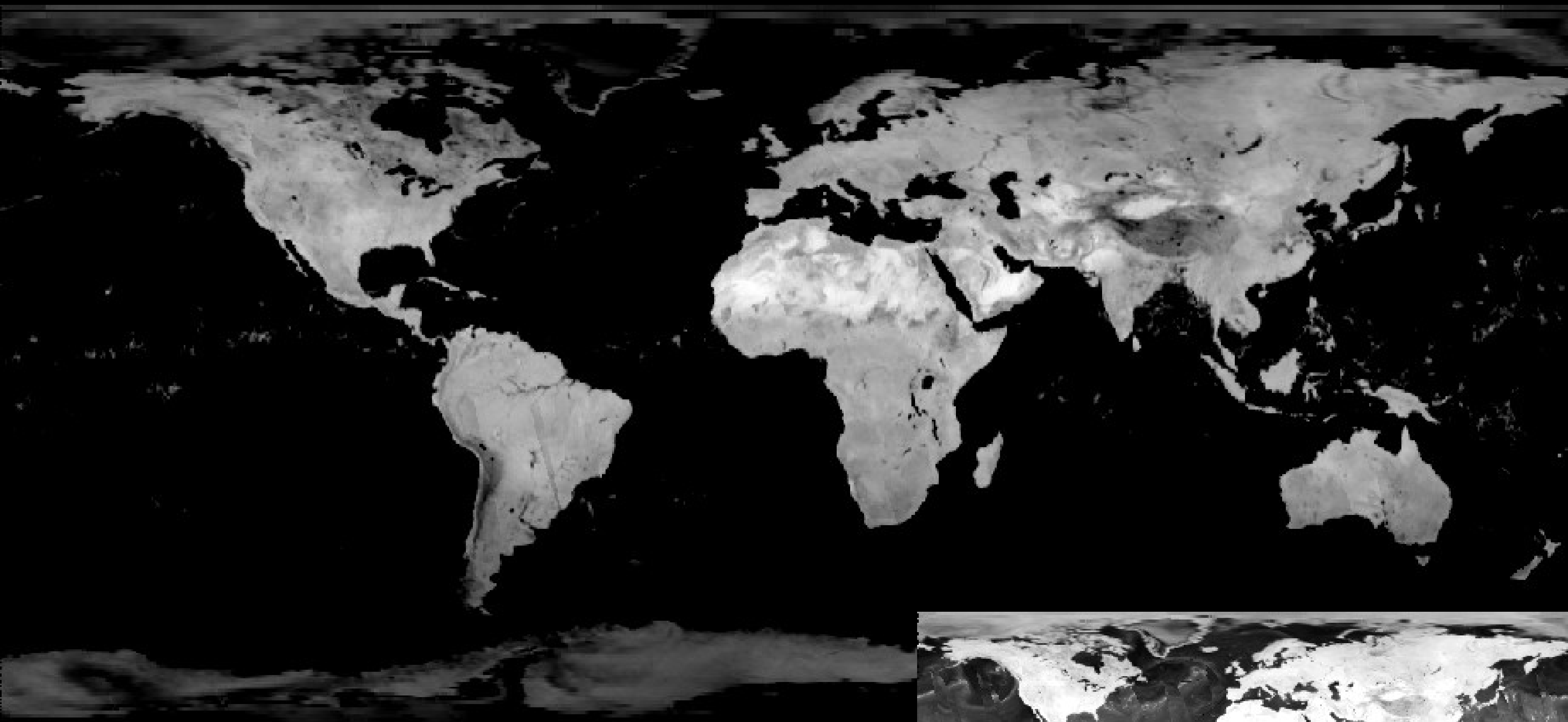
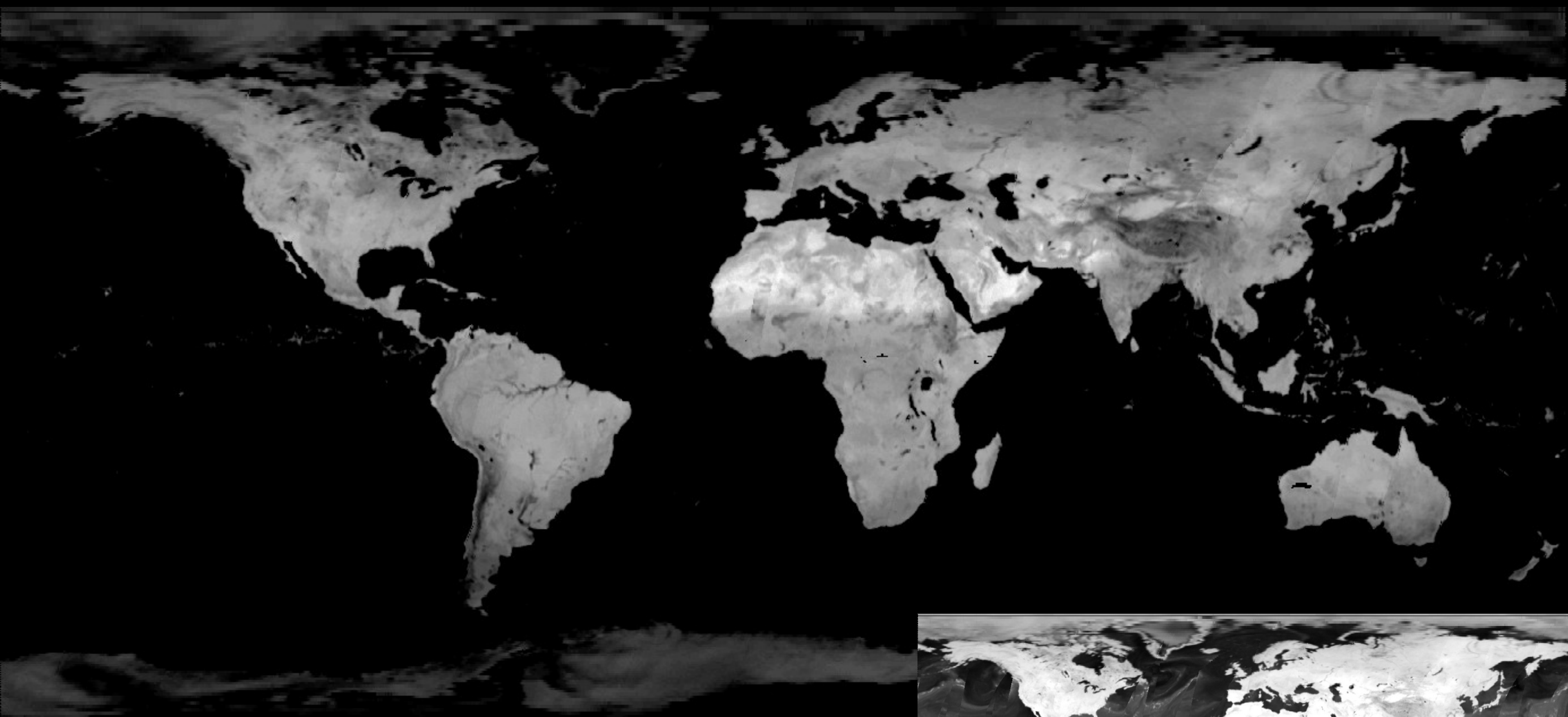


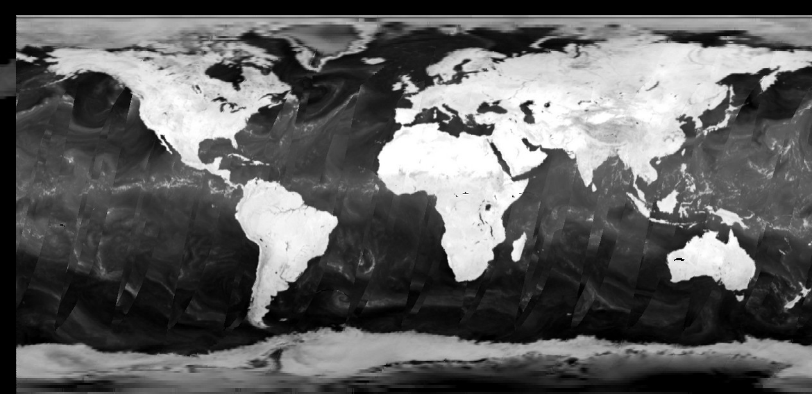
Image globale SSM/I (19GHz)
Brightness Temperature –V polarization
3-8 août 1991



Nœud ascendant: 6 h

Image globale SSM/I (19GHz)
Brightness Temperature – H Polarization
3-8 août 1991



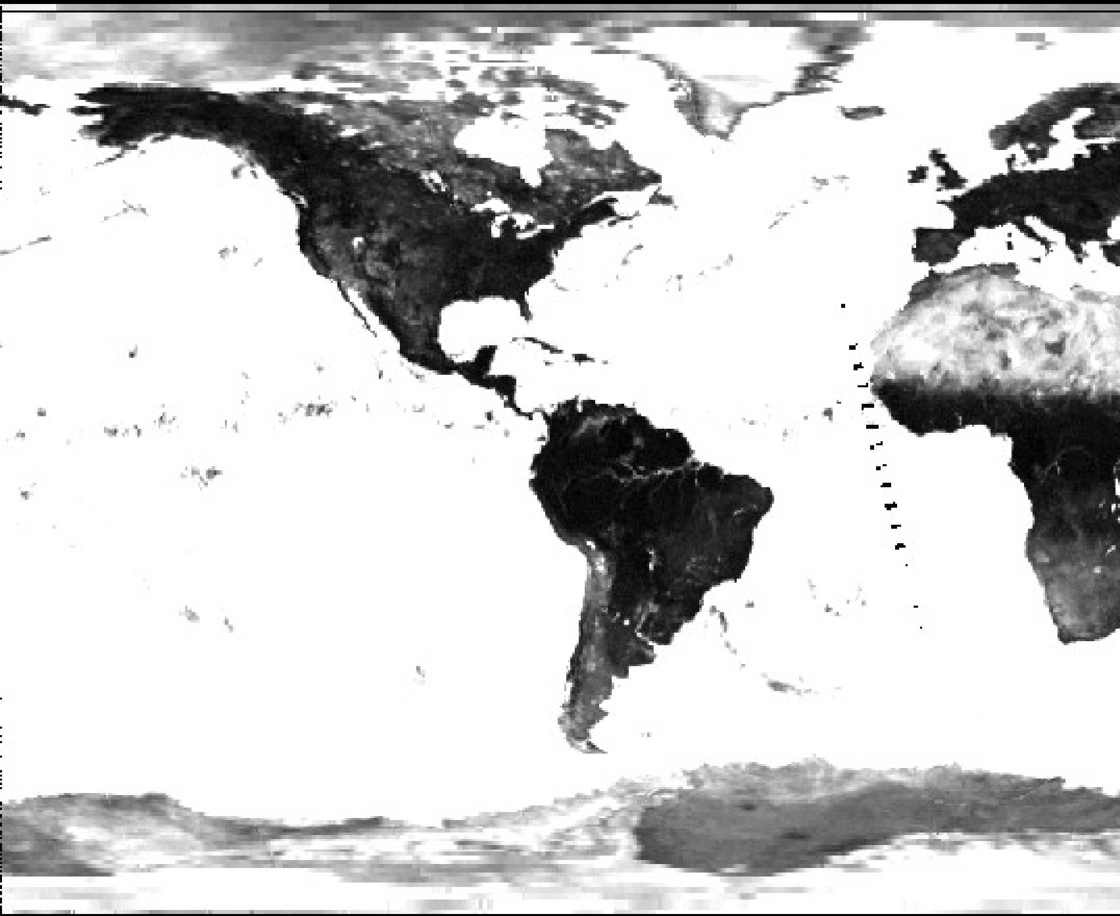


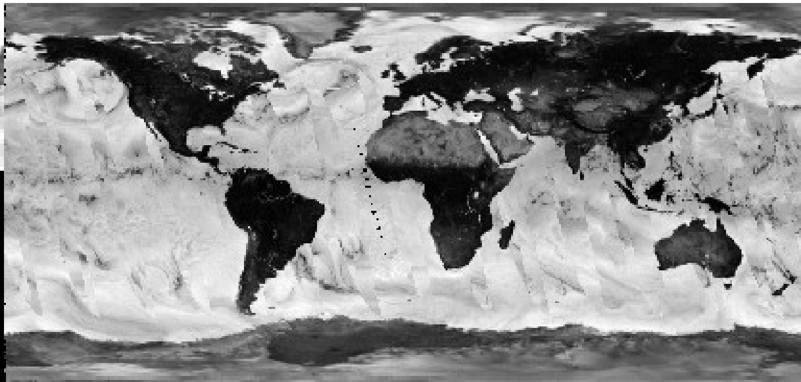
Nœud descendant: 18 h

Image globale SSM/I (19GHz)

$\Delta T = T_V - T_H$

3-8 août 1991



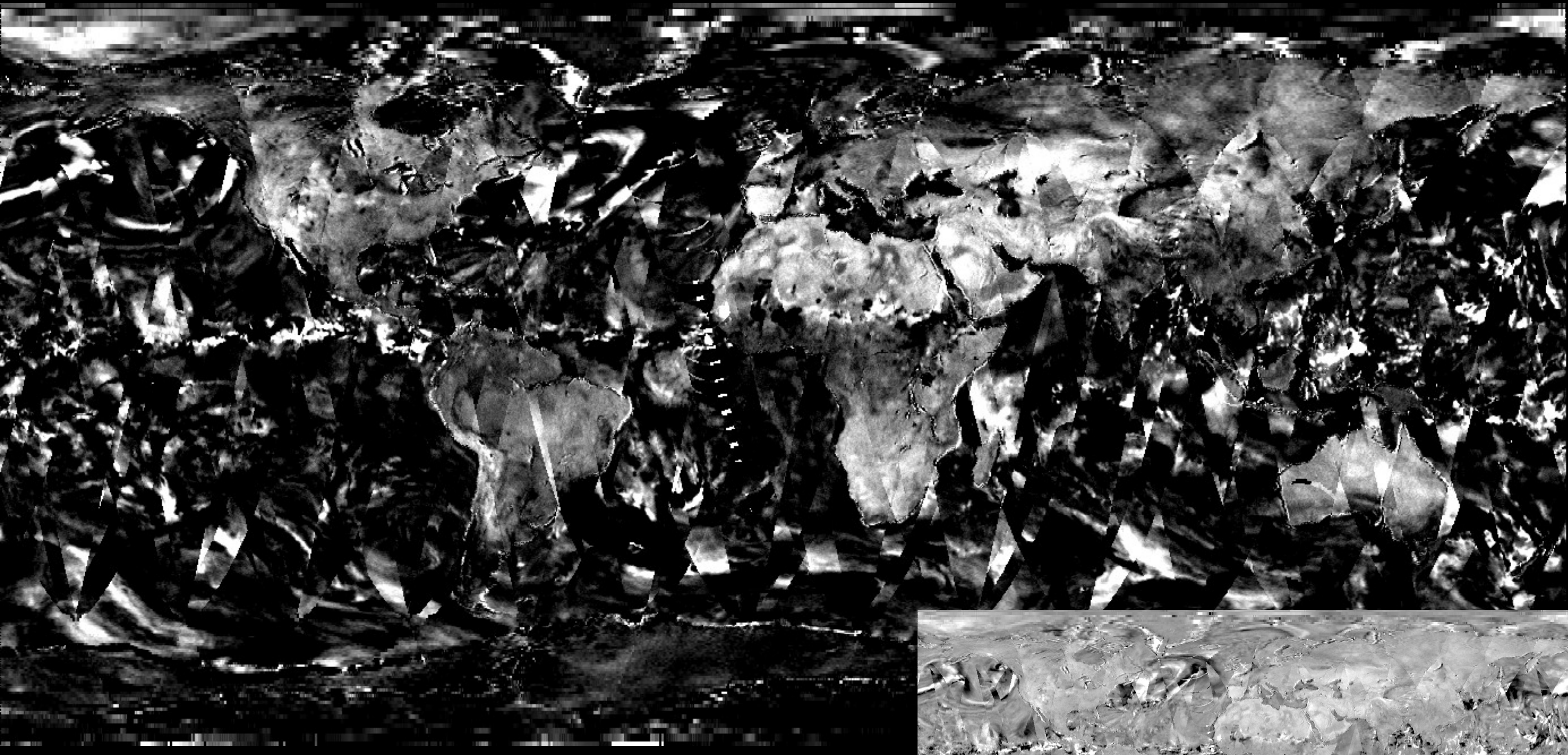


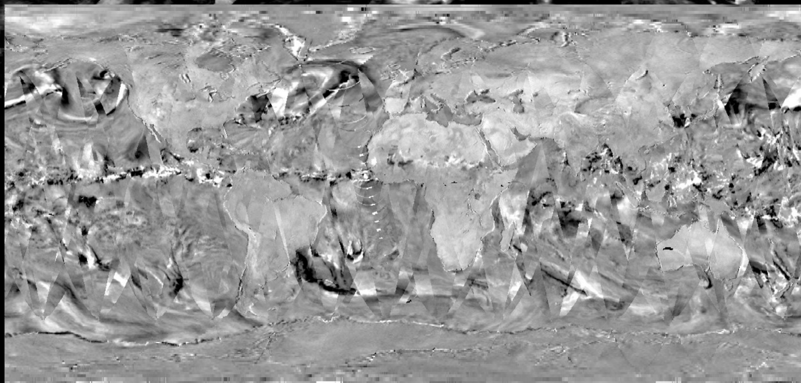
Nœud ascendant: 6h

Image globale SSM/I (19GHz)

T_{PM} - T_{AM} pol. V

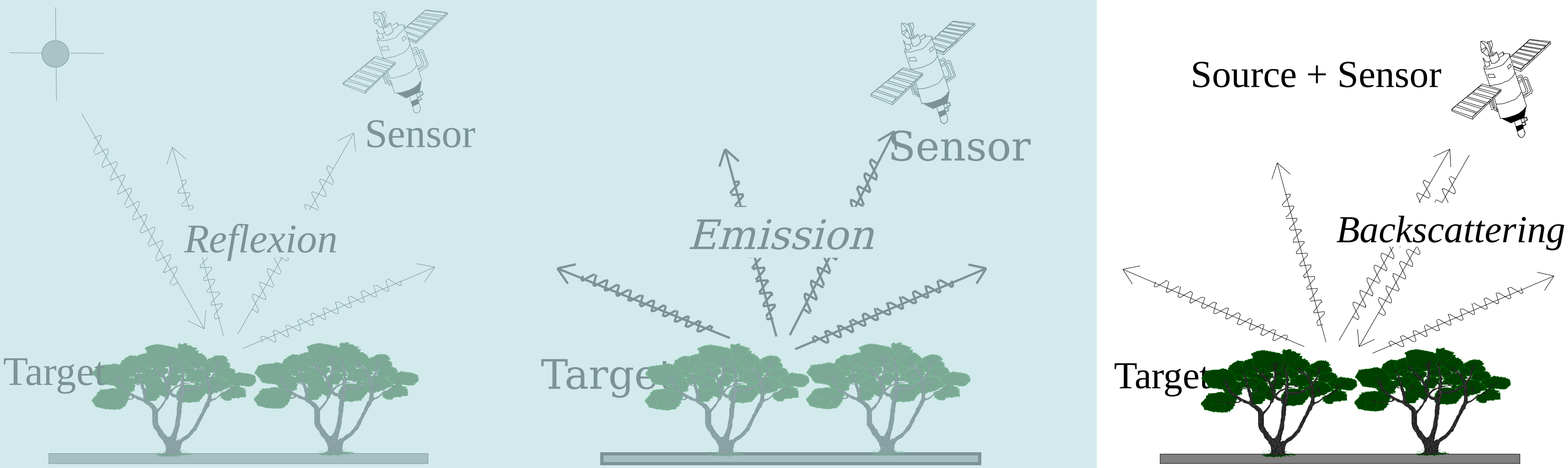
3-8 août 1991





RADAR Remote Sensing
cm - m

Observation modes



VIS
NIR, MIR

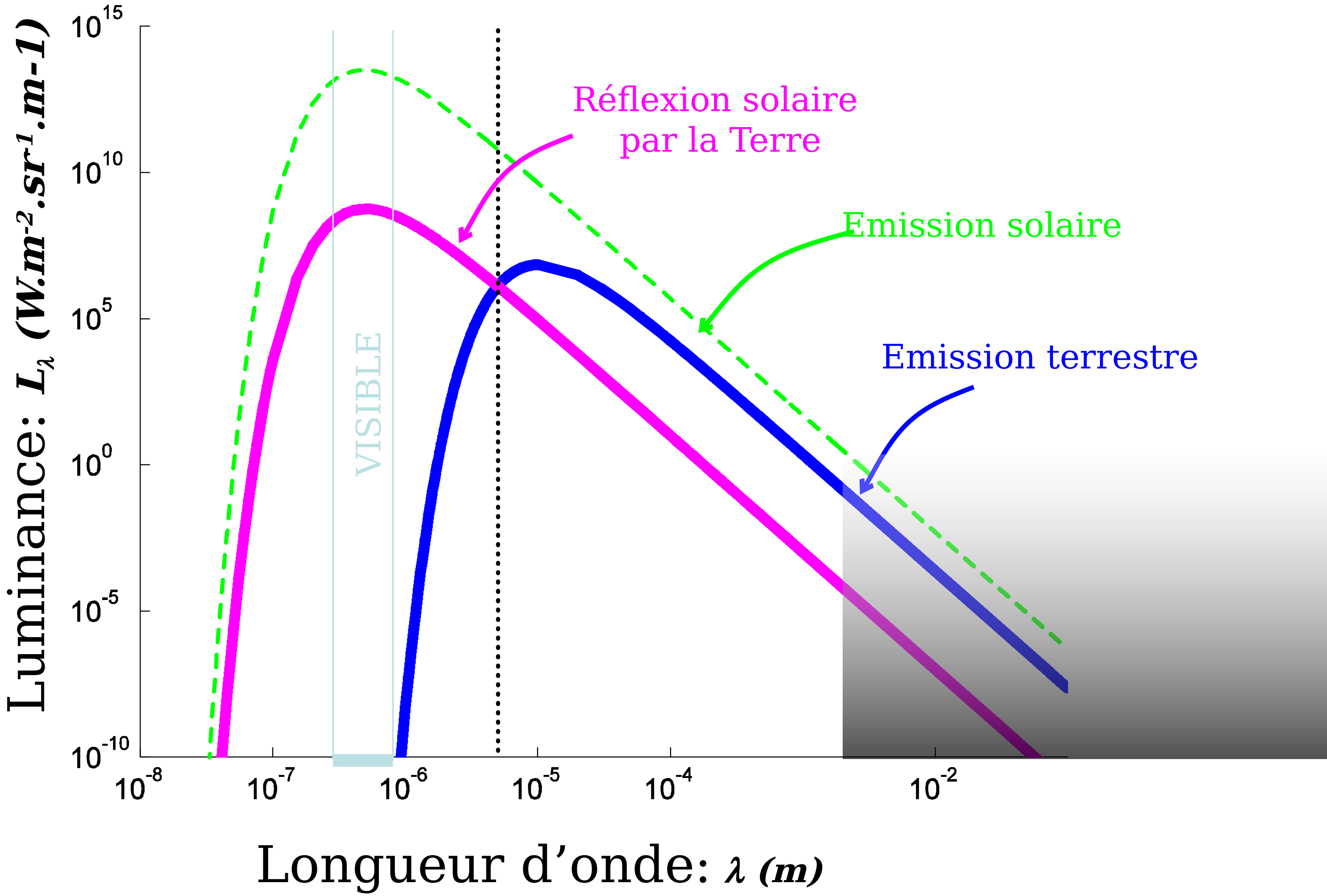
TIR
Microwav
es

‘active’
microwaves

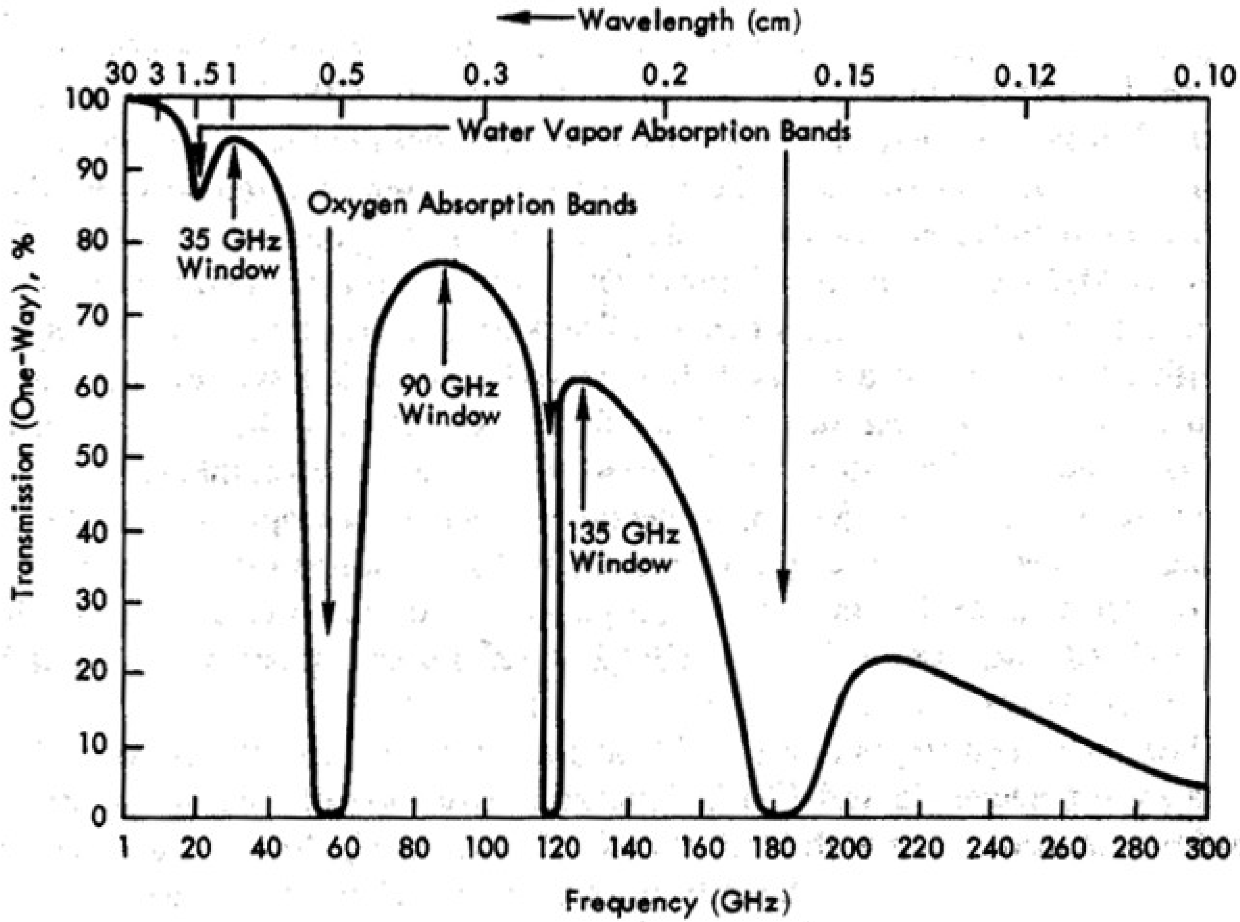
VIS | NIR-MIR-TIR | Microwaves

0.4-0.7 µm | 0.7-7500 µm | 0.75-150 cm

Hyperfréqences actives: RADAR



Microwave spectrum behaviour



Source: Ullaby *et al.*

Radar imageur SAR: un système tout temps

ERS (bande C, 23°, VV)

Landsat TM

Waterford, Irelande, 09/08/91

Surface: 50 x 50 km

Passage Landsat: 10h43

Passage ERS-1: 11h25

Source ESA

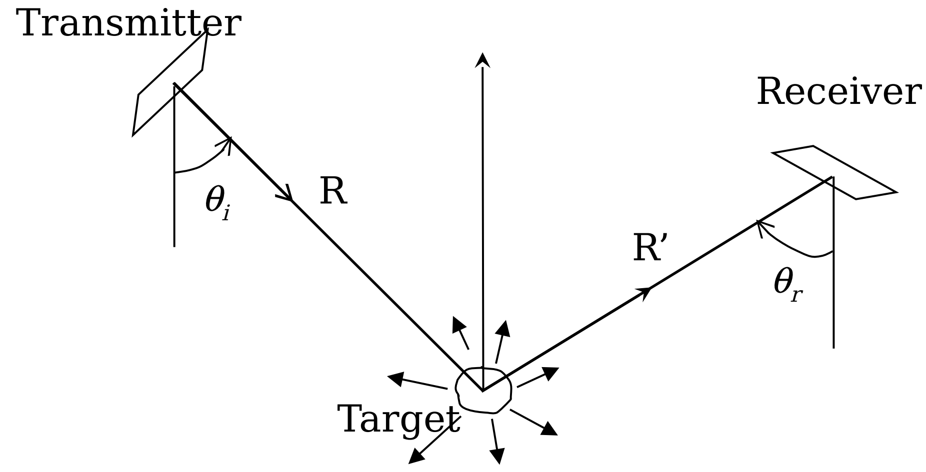
r: système actif => - image de jour comme de nuit

- observation hautes latitudes

s centimétriques => insensible conditions météorologiques

(10% des images optiques sont sans nuages sur l'Europe)

The RADAR equation



ransmitted power by the radar:

$$P_i = \frac{P_e G_e}{4\pi} d\Omega$$

eceived irradiance at distance R:

$$E_i = \frac{P_e G_e}{4\pi R^2}$$

tercepted power by the target: $P_s = \frac{P_e G_e}{4\pi R^2} RCS$

Radar Cross Section (m^2)

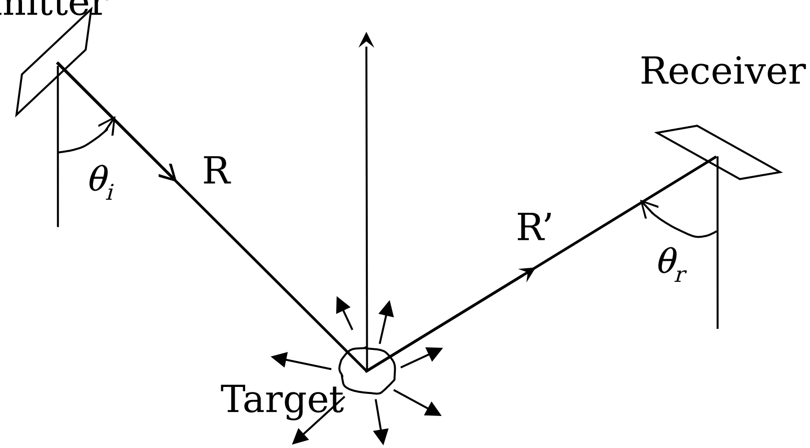
lected intensity by the target (cons. isotrope): $I = \frac{P_S}{4\pi} = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi}$

ceived power by the surface dS at distance R': $P_r = I d\Omega = I \frac{dS}{R'^2} = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi R'^2} dS$

The RADAR equation (2)

Received power by dS at distance R':

$$P_r = \frac{P_e G_e}{4\pi R^2}\frac{RCS}{4\pi R'^2}dS$$



Received irradiance at distance R':

$$E_r = \frac{P_e G_e}{4\pi R^2}\frac{RCS}{4\pi R'^2}$$

Received power by the antenna:

$$P_r = E_r\, dA = E_r \frac{G_r \lambda^2}{4\pi} = \frac{P_e G_e}{4\pi R^2}\frac{RCS}{4\pi R'^2}\frac{G_r \lambda^2}{4\pi}$$

The RADAR equation (3)

Received power by the antenna: $dP_r = \frac{P_e G_e}{4\pi R^2} \frac{RCS}{4\pi} \frac{G_r \lambda^2}{4\pi R^2}$

Case of surfaces:

Backscattering Radar Coefficient: $\sigma^0 = \frac{SER}{d\Sigma}$ (m²/m²)

$$dP_r = \frac{P_e G_e}{4\pi R^2} \frac{\sigma^0 d\Sigma}{4\pi} \frac{G_r \lambda^2}{4\pi R^2}$$

$$\boxed{\langle P_r \rangle = \frac{\lambda^2}{(4\pi)^3} \frac{P_e \sigma^0}{R^4} \iint_{Surf.obs.} G_e G_r \, d\Sigma}$$

Télédétection radar (λ > cm)