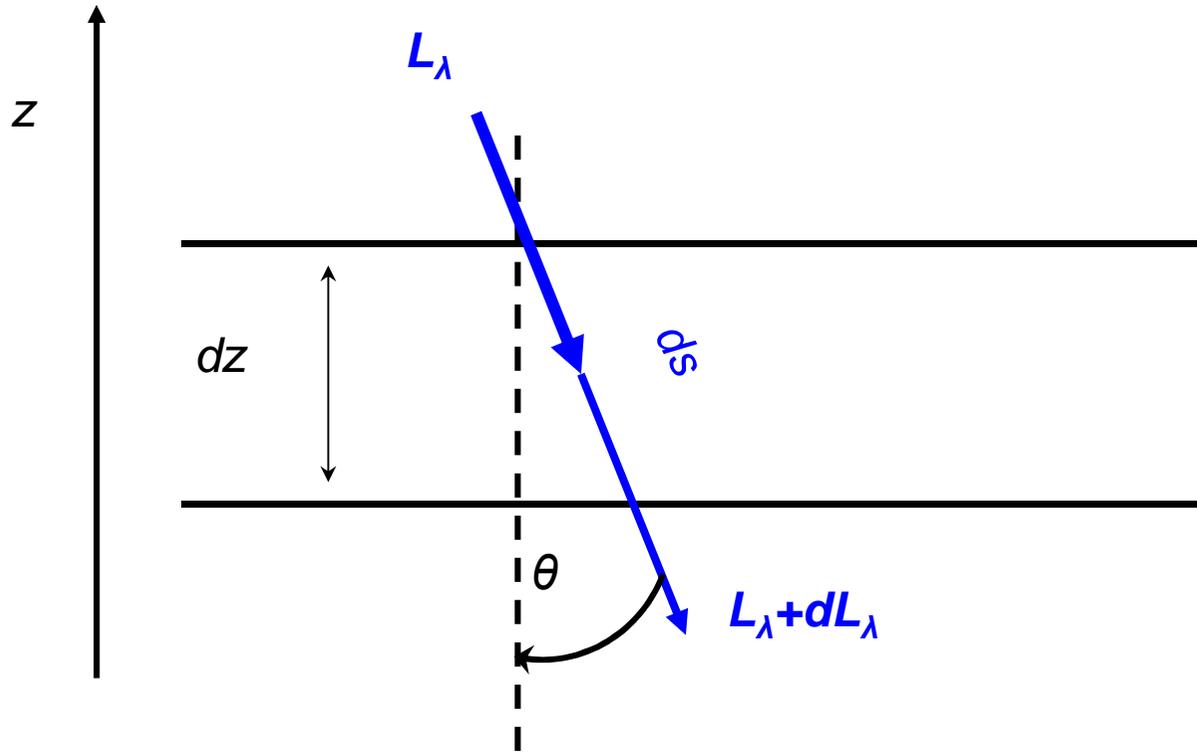


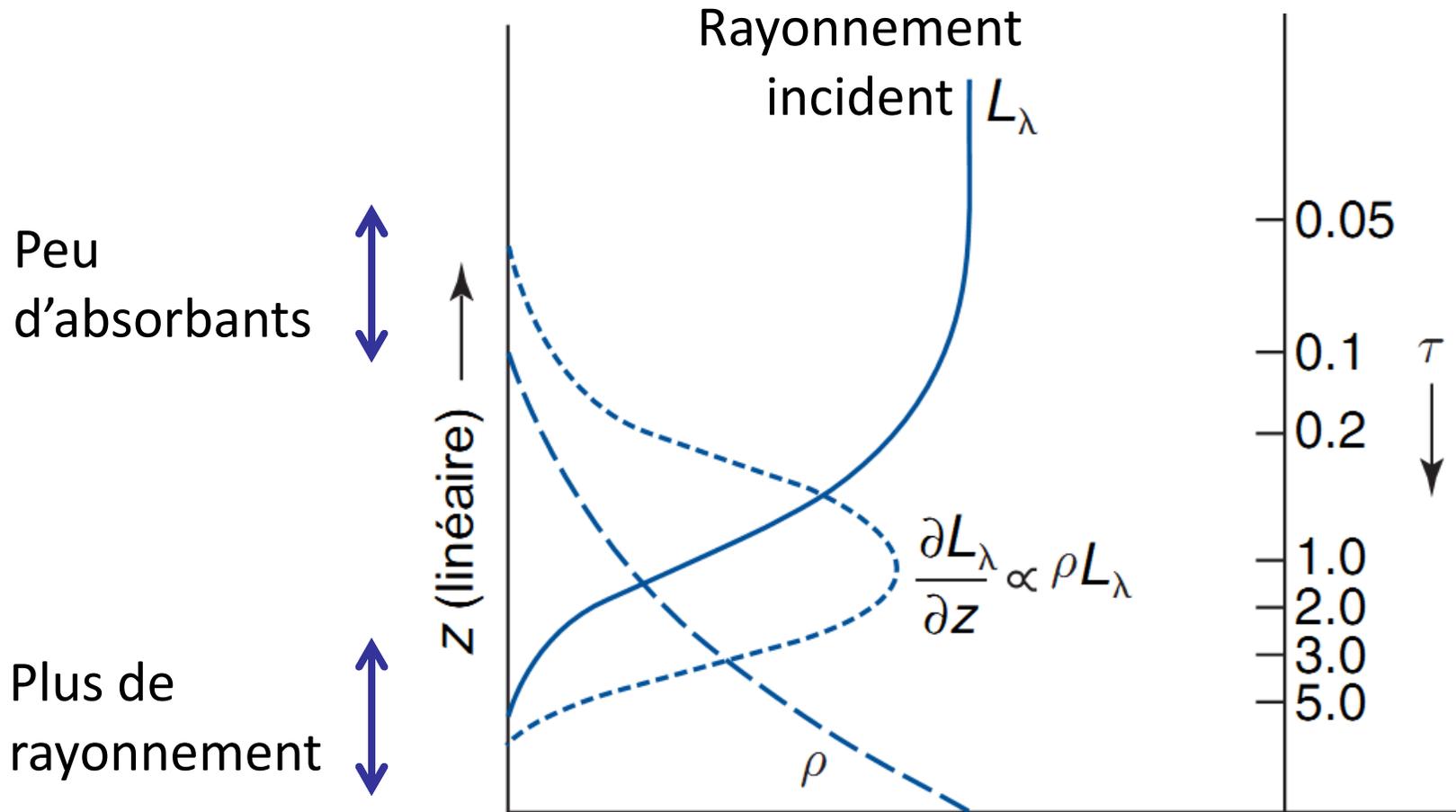
# 1. Absorption



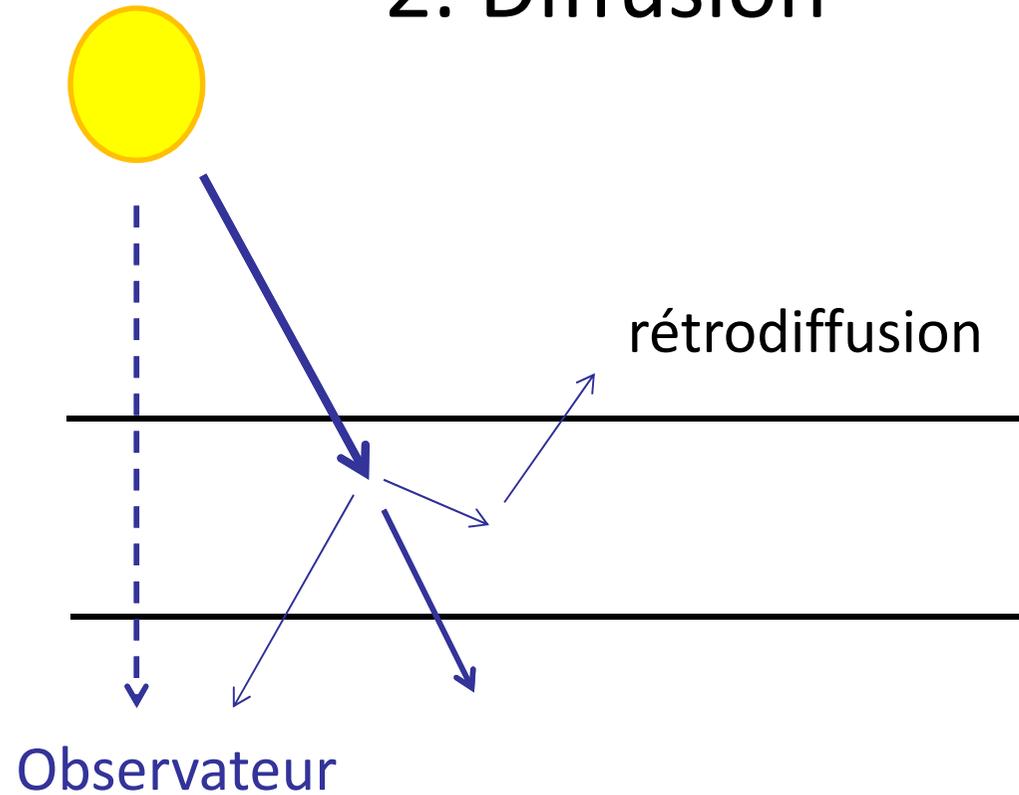
Épaisseur optique:  $dL = -Lk_a\rho_a ds = -Ld\tau$   
 $L = L^\infty e^{-\tau}$

$\tau$  = quantité d'absorbants intégrée.

# Taux maximum d'absorption: $\tau = 1$



## 2. Diffusion



*Rayleigh*: molécules, peu efficace,  $\sigma \propto \lambda^4$  ciel bleu

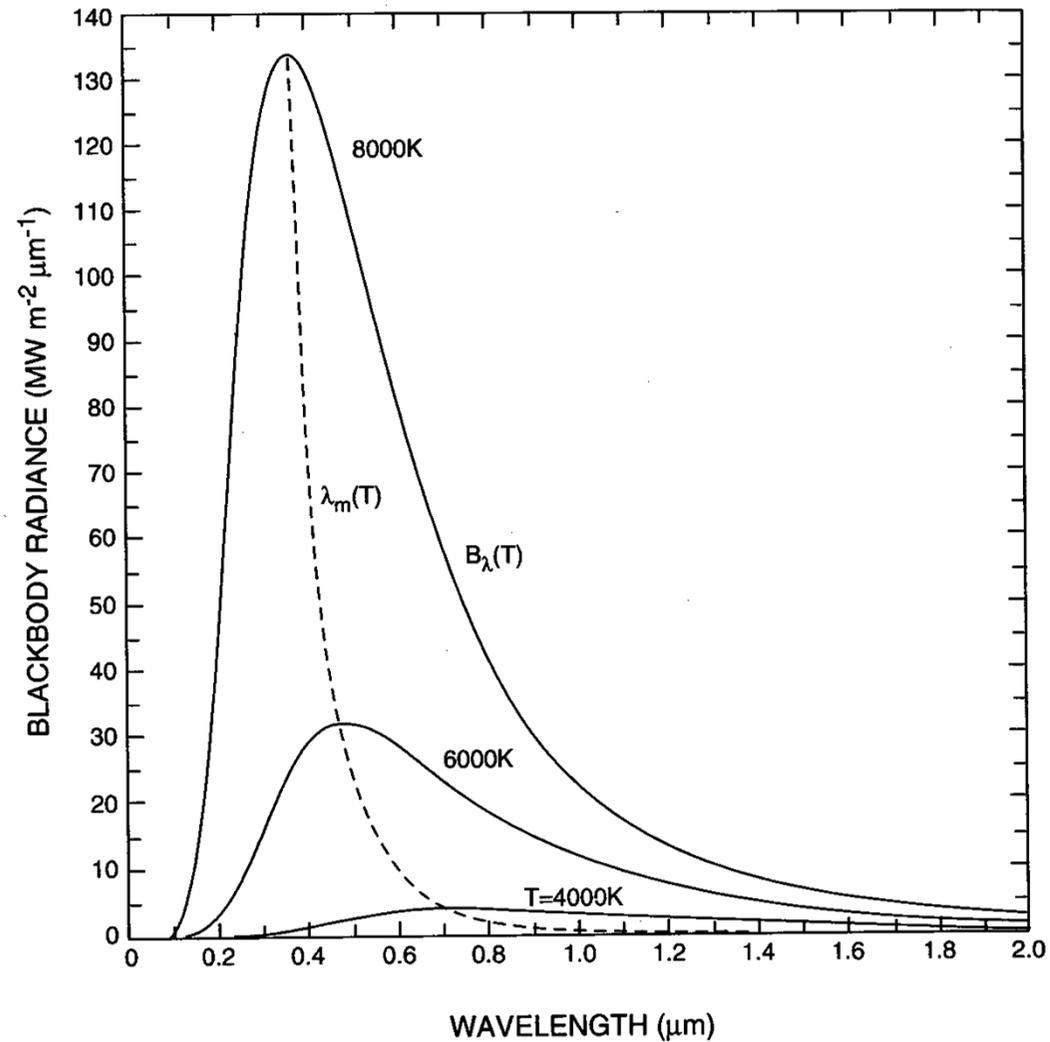
*Géométrique*: particules (gouttes...), très efficace. Nuages blancs

### 3. Émission: lois du corps noir

Flux total =

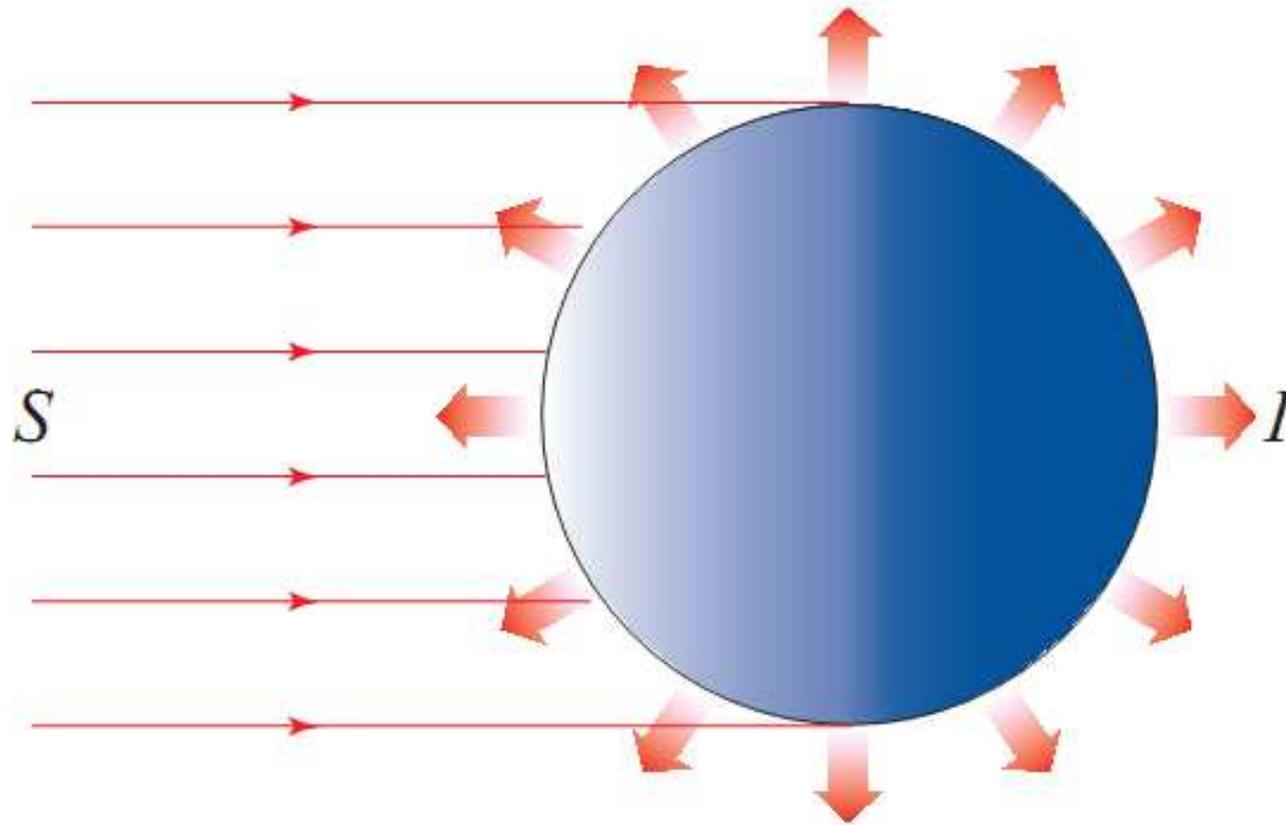
$\lambda_{\text{maximum}} =$

Kirchoff:





Rayonnement solaire:  
Éclairement moyen  $E=S/4$

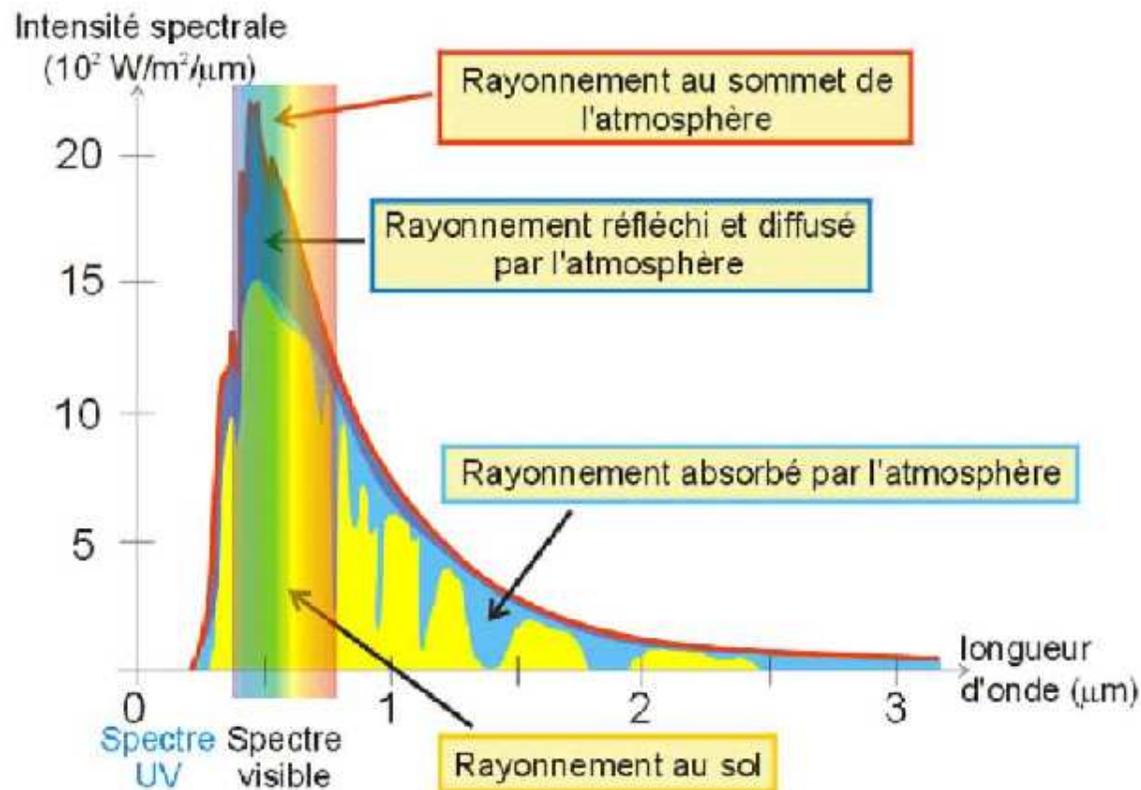


Flux solaire intercepté:  
 $S \cdot \pi R_T^2$

Surface de la Terre:  
 $4\pi R_T^2$

# Transfert radiatif dans le visible

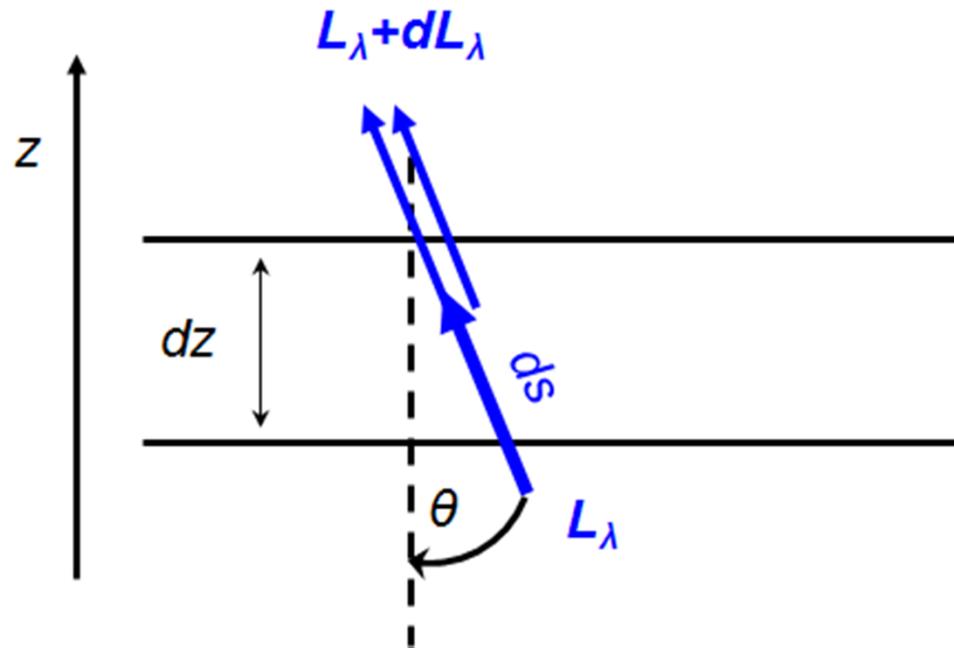
- Absorption
- Diffusion et rétrodiffusion (albédo planétaire ~ 0,3)



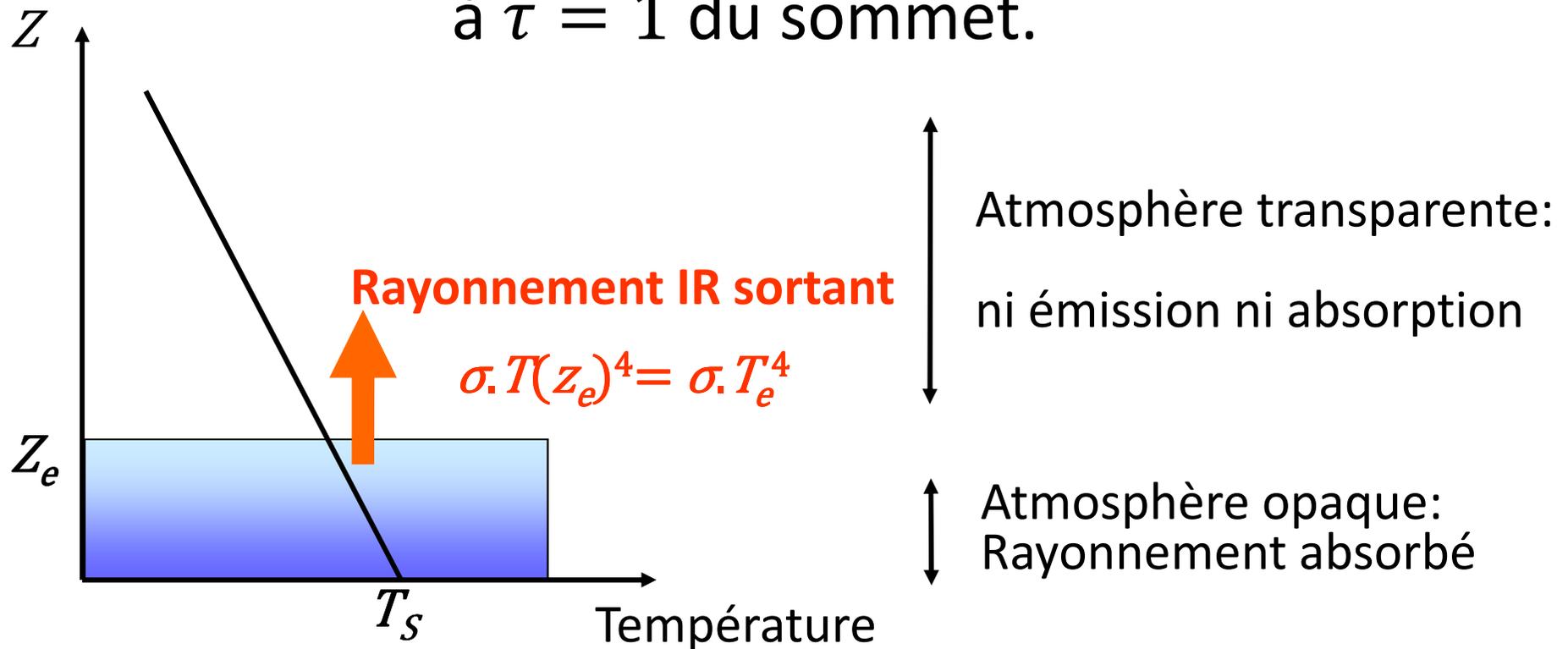
Type de Surface	Albédo (%)
<i>Sol nu</i>	
Roches sombres, humus	10
Sol sec, désert	30
Sable mouillé	25
Sable clair, sec	35
Asphalte	7
Béton	20
<i>Végétation</i>	
Végétation basse, verte	17
Végétation sèche	25
Forêt conifères	12
Forêt décidue	17
<i>Neige et glace</i>	
Forêt avec neige au sol	25
Banquise sans neige	30
Neige fondante	50
Neige fraîche	80

# Rayonnement Infrarouge

- Pas de diffusion
- Absorption et émission (loi de Kirchoff)

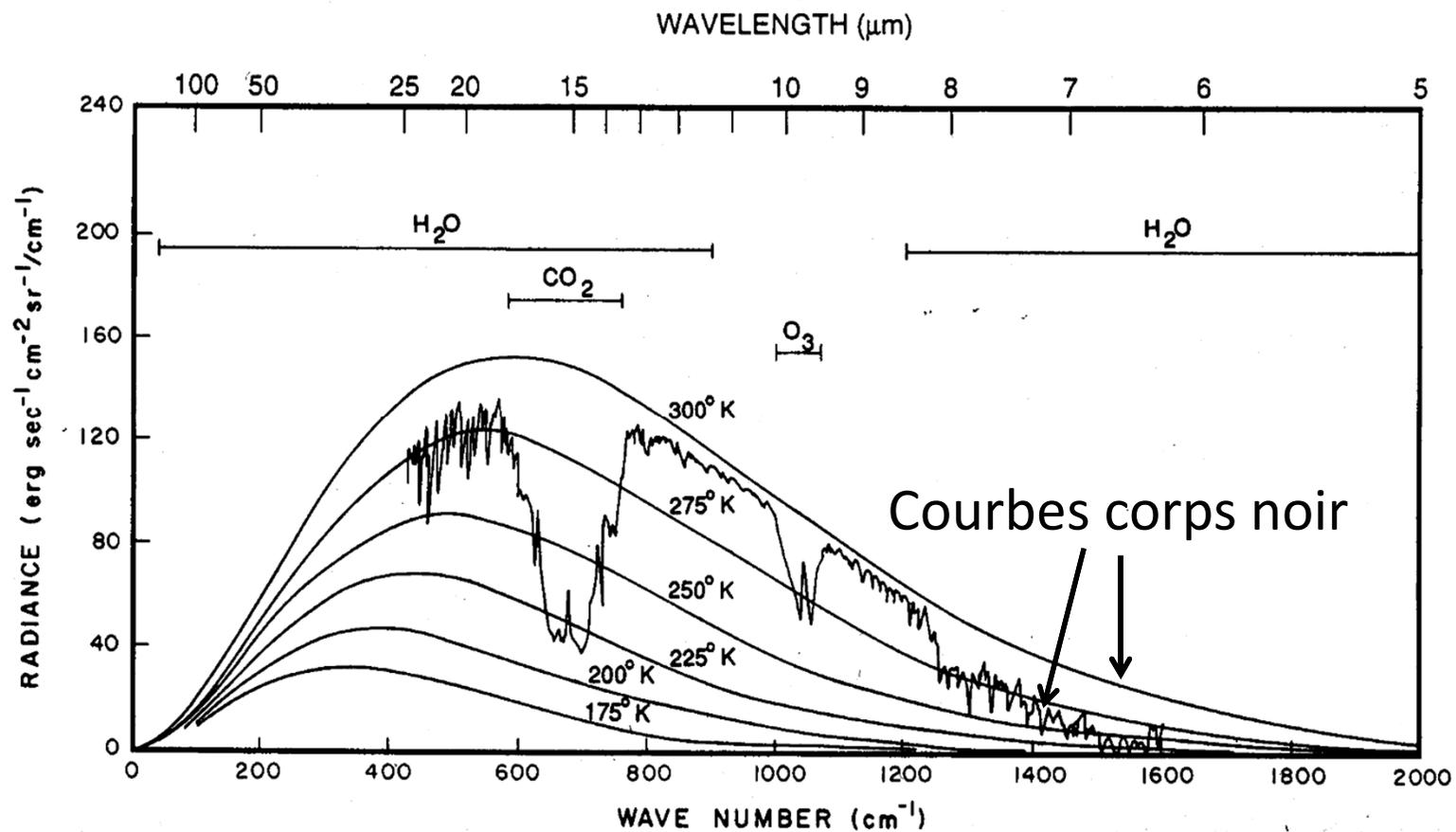


# Maximum d'émission vers l'espace à $\tau = 1$ du sommet.



- *Température d'émission  $T_e$ : ray<sup>t</sup> sortant =  $\sigma T_e^4$*
  - *Altitude d'émission  $T(z_e) = T_e$*
- En général, si  $z_e$  est élevée,  $T_e$  est faible.

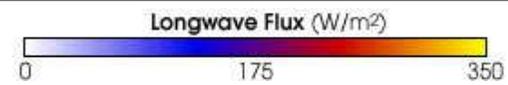
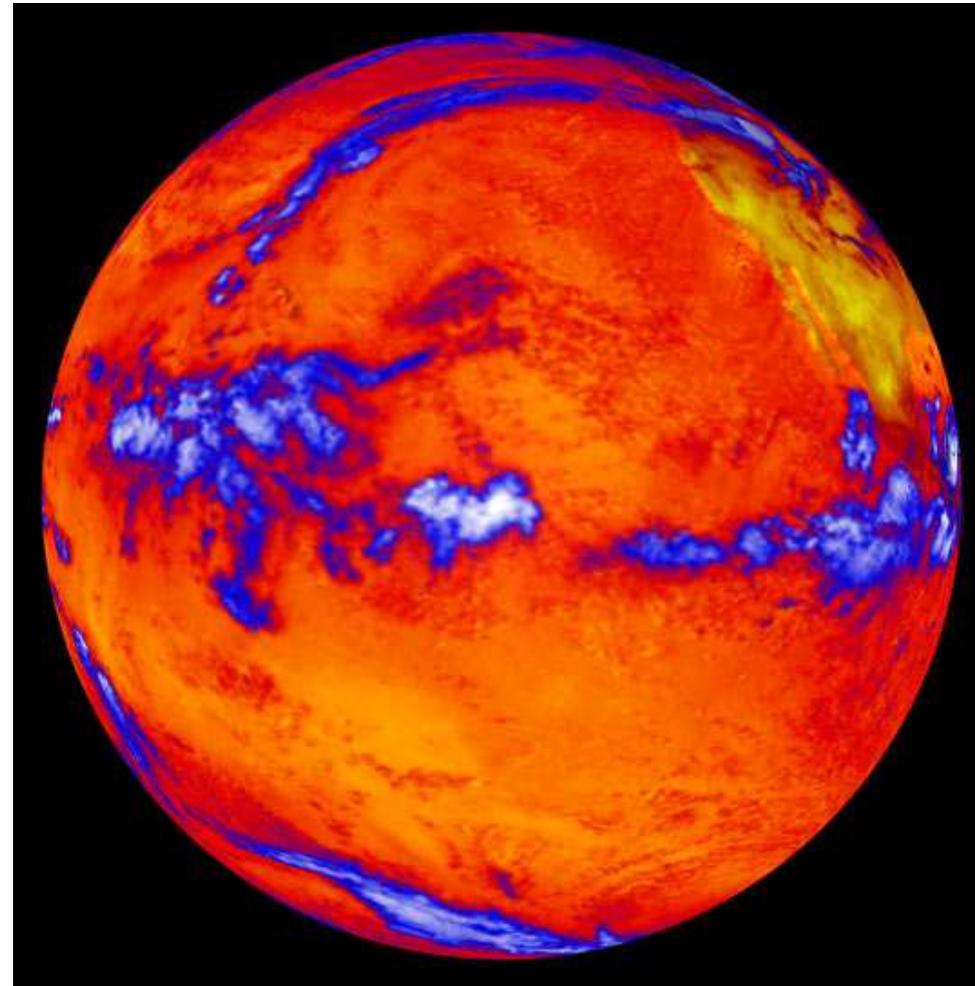
# Variations de $\epsilon$ selon



Rayonnement sortant

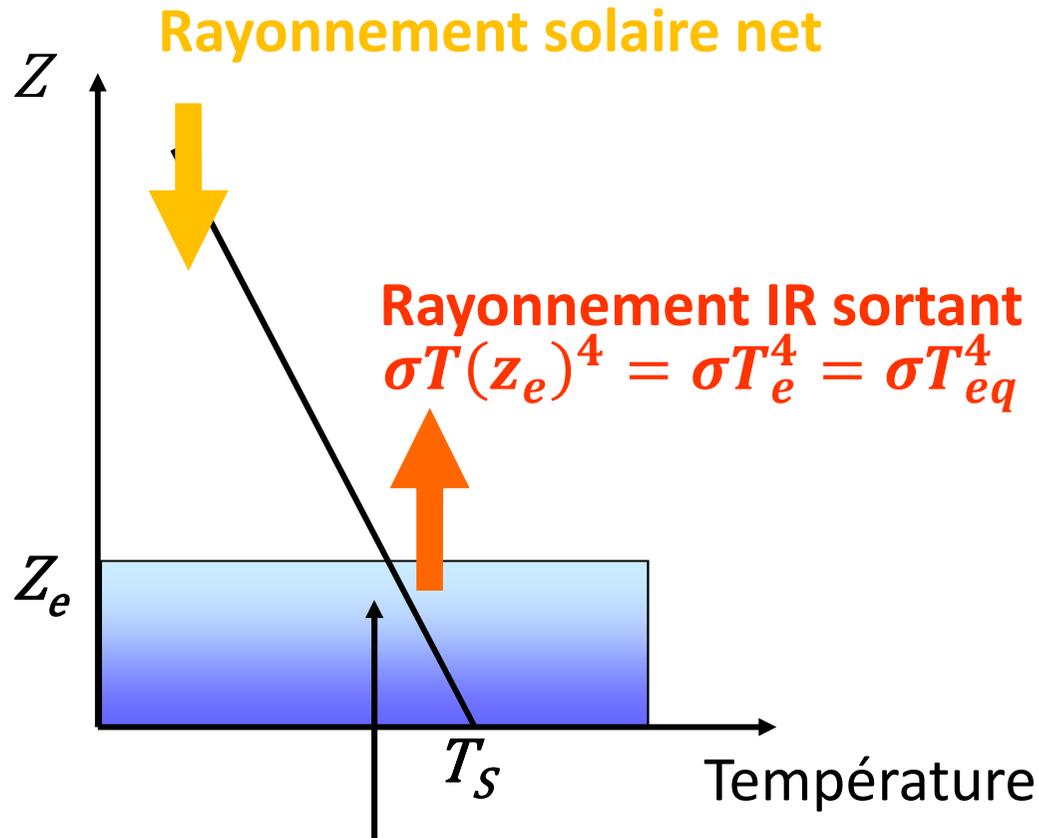
# Variations géographiques de $T_e$

Flux sortant  
Total observé



## Equilibre radiatif global:

$$\text{Température équivalente } \sigma T_{eq}^4 = (1 - \alpha)S/4$$



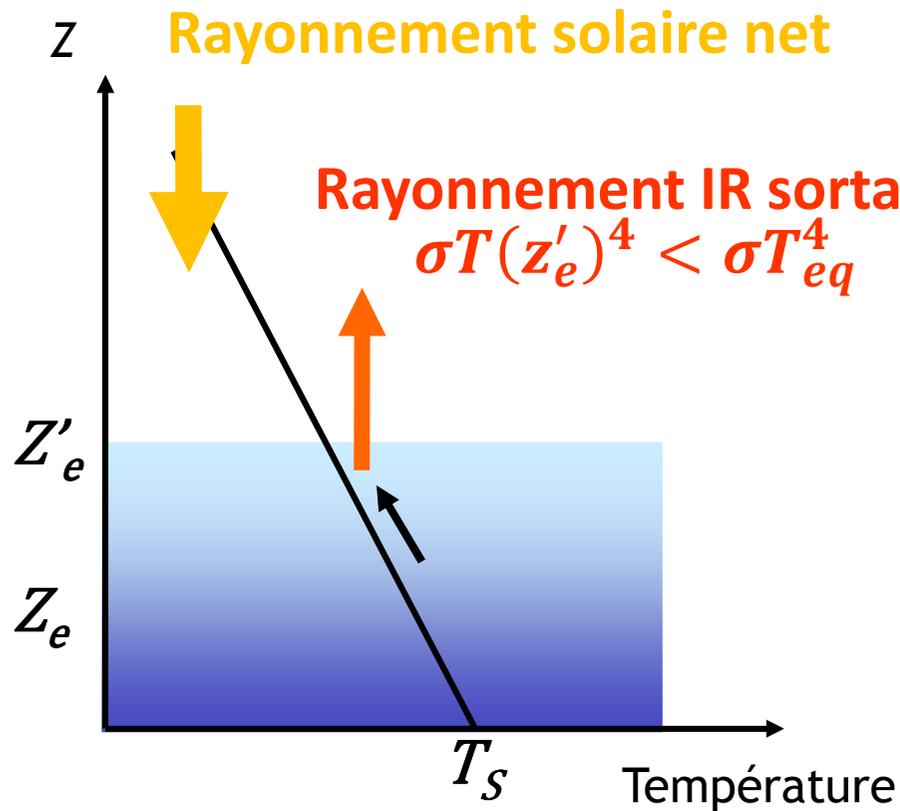
Effet de serre  $\epsilon$ :

$$T_e < T_s$$

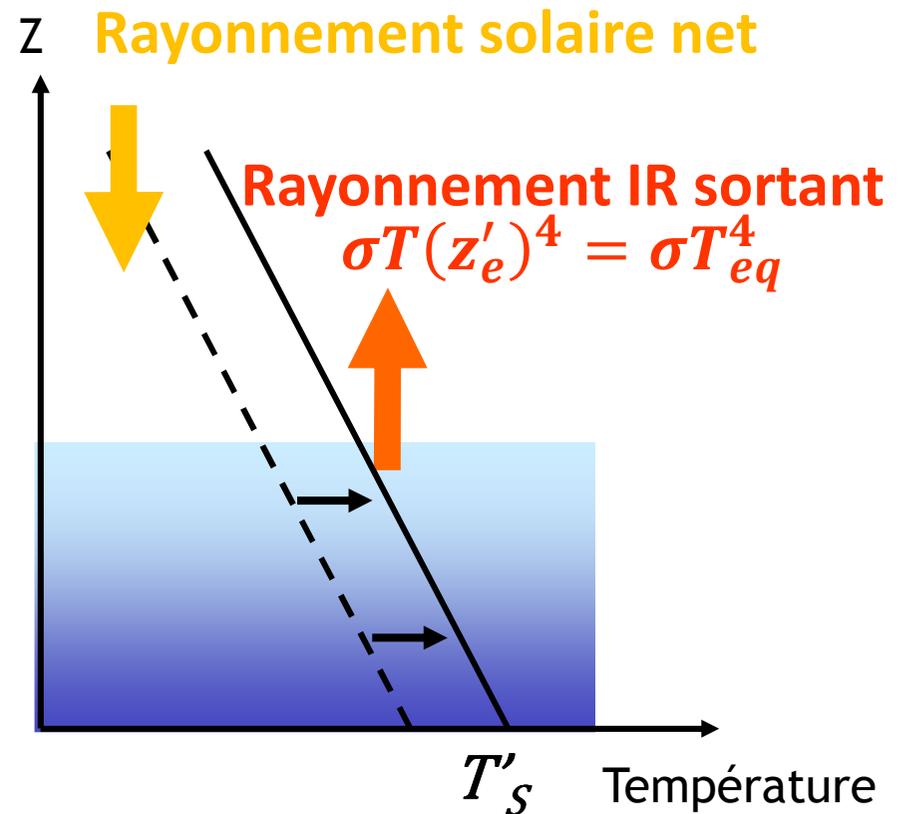
(profil vertical), donc

$$\sigma T_{eq}^4 = (1 - \epsilon)\sigma T_s^4$$

Augmentation de gaz à effet de serre:  
 Altitude d'émission vers l'espace plus élevée  
 Augmentation de la température.

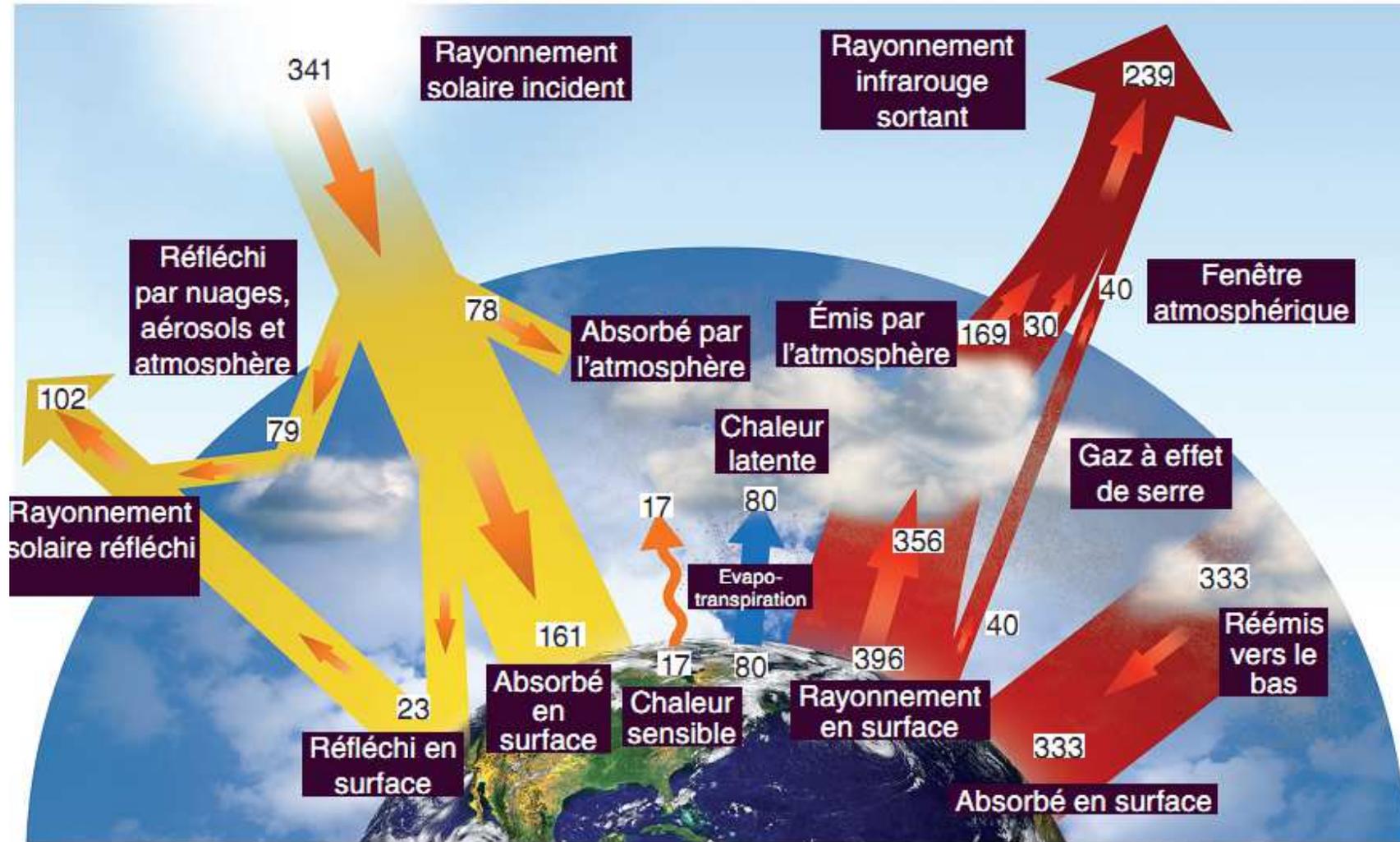


1.  $T_{\text{émission}}$  diminue ( $z_e$  plus élevée):  
 Rayonnement sortant plus faible.



2.  $T(z)$  augmente:  
 Retour à l'équilibre

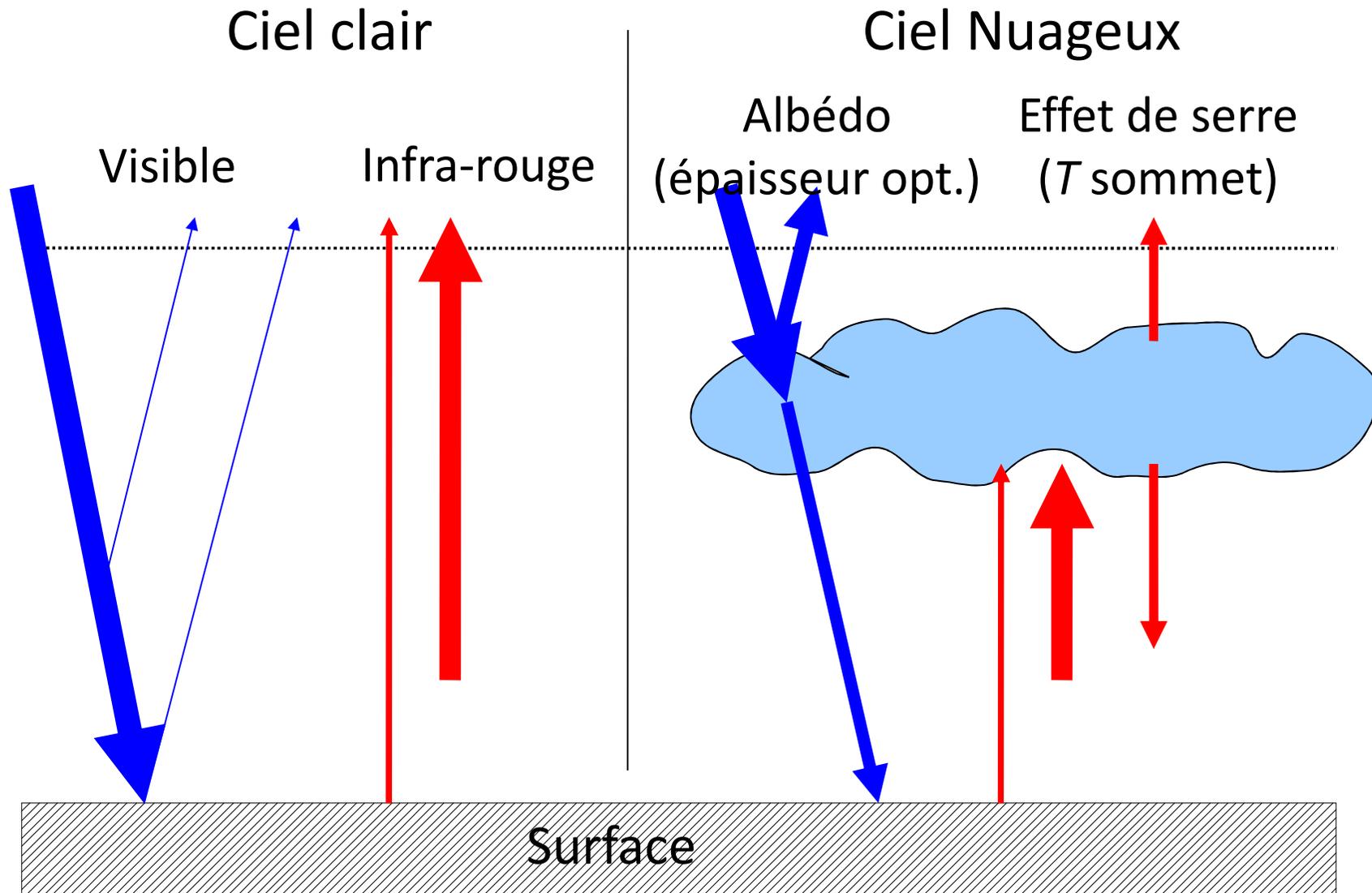
# Bilan énergétique global (flux en $W m^{-2}$ )



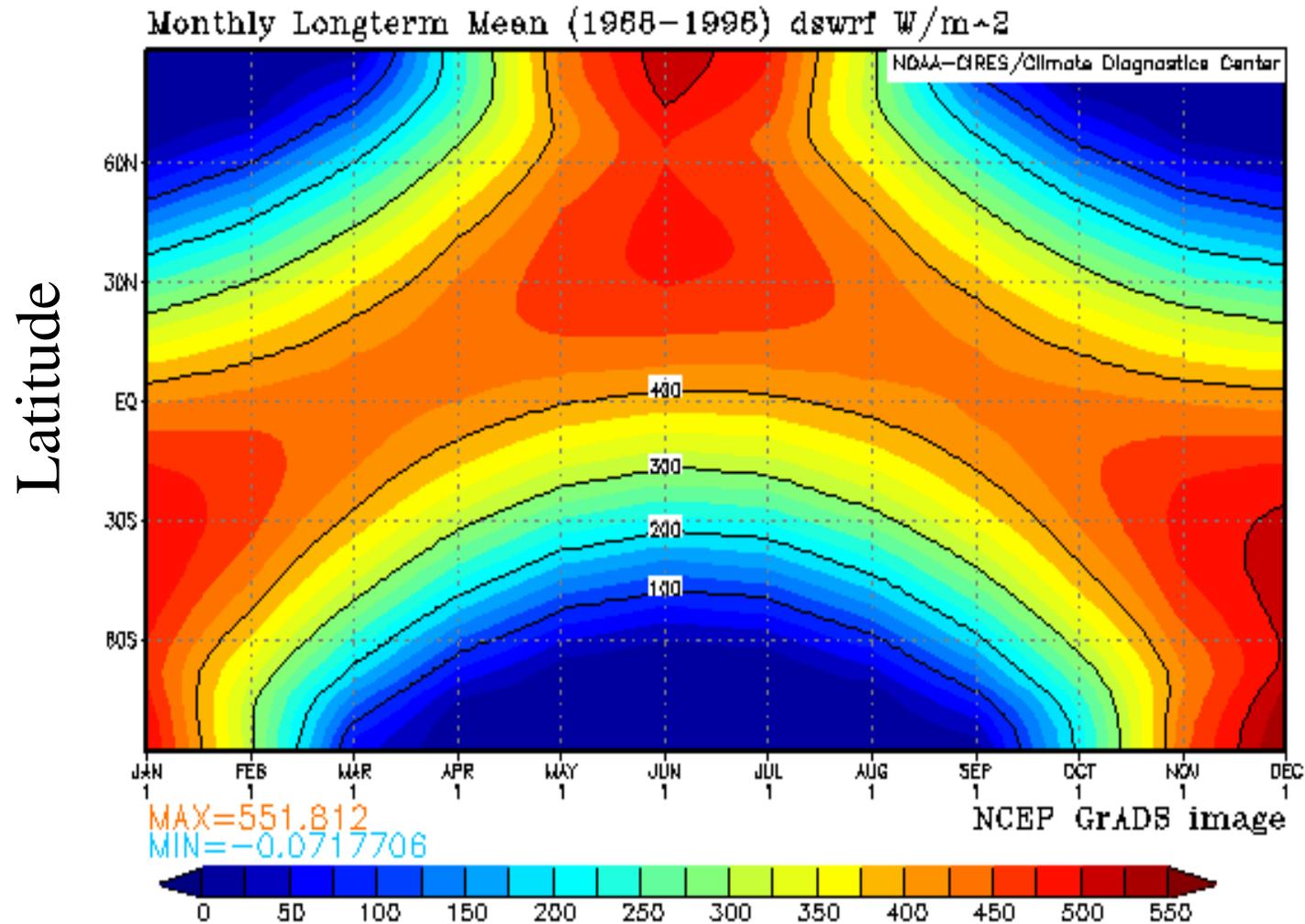
Rayonnement solaire

Rayonnement IR terrestre

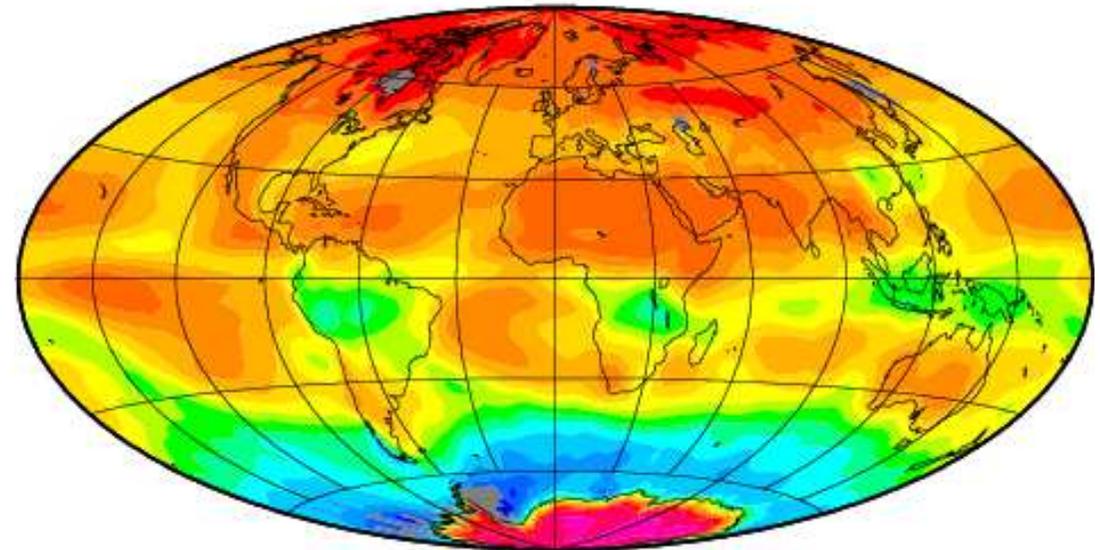
# Forçage radiatif des nuages



# Flux solaire sommet de l'atmosphère: Cycle saisonnier



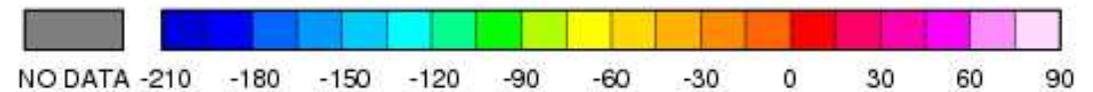
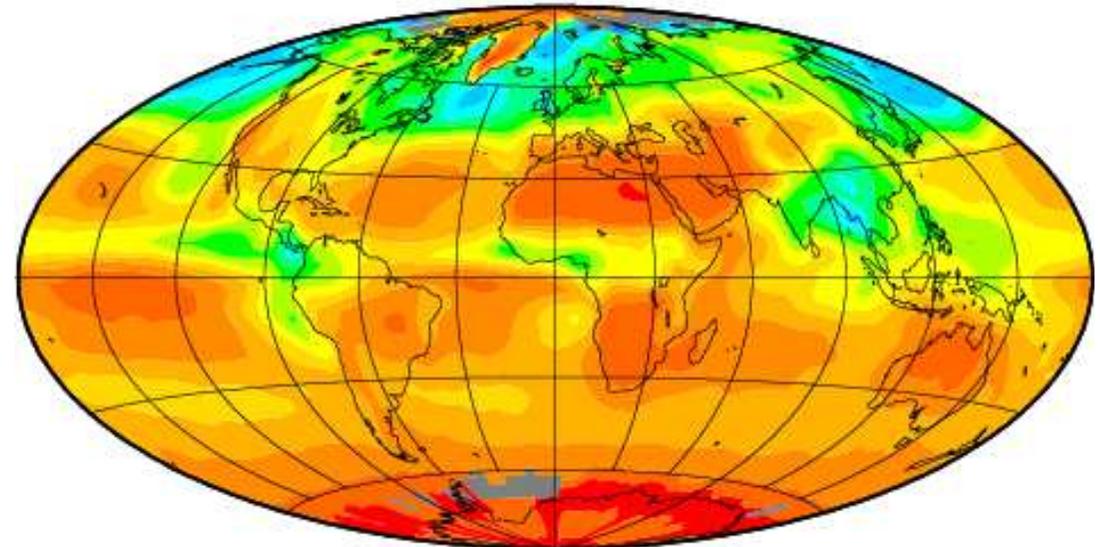
Dec-Jan-Fév



Shortwave Cloud Forcing  
JJA 1985-1986

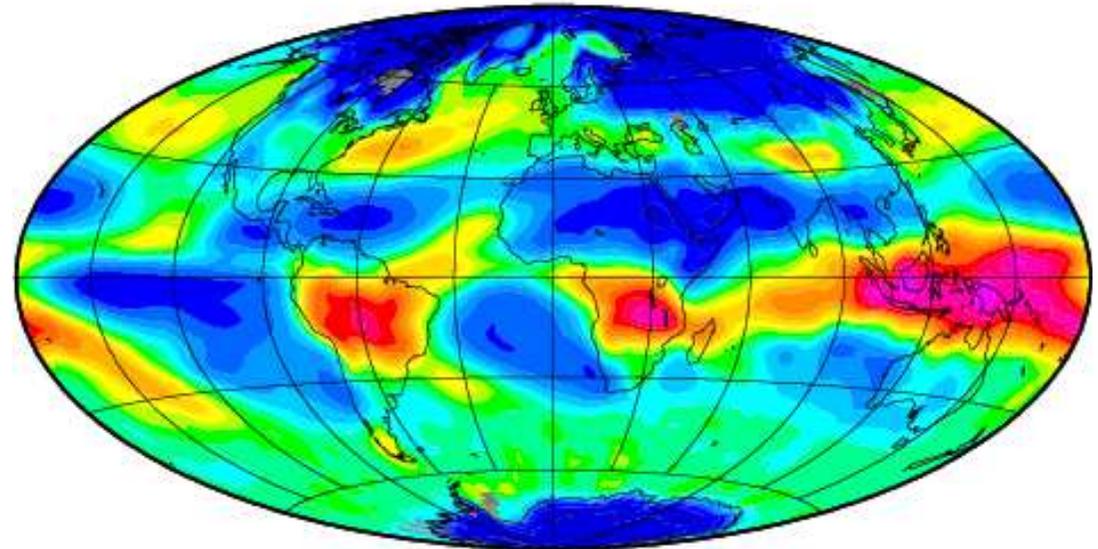
Forçage radiatif visible  
des nuages:

Juin-Juil-Août



W/m<sup>2</sup>

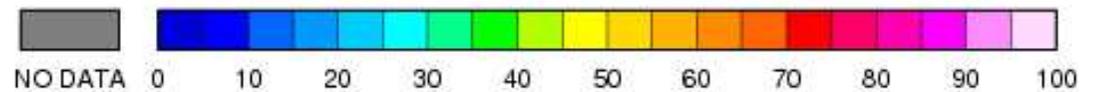
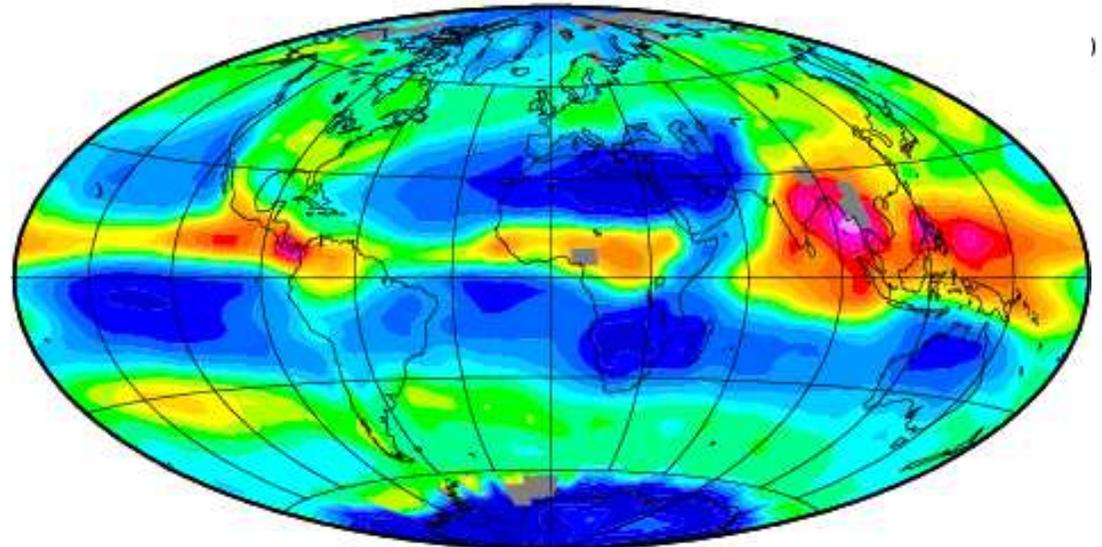
Dec-Jan-Fév



Longwave Cloud Forcing  
JJA 1985-1986

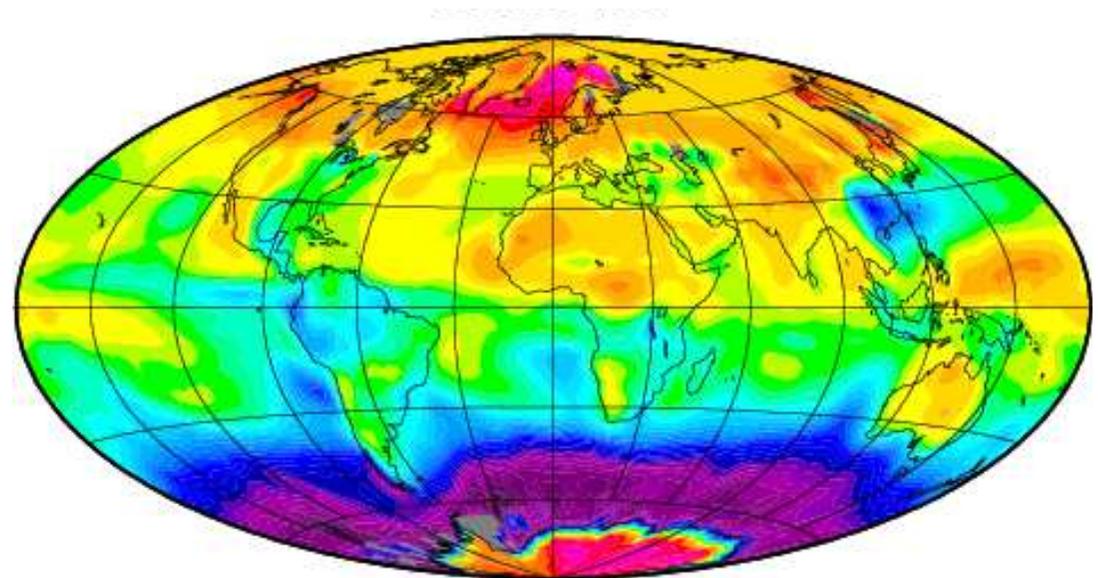
# Forçage radiatif Infra-Rouge des nuages:

Juin-Jul-Août



W/m\*\*2

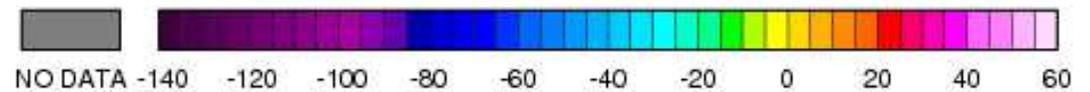
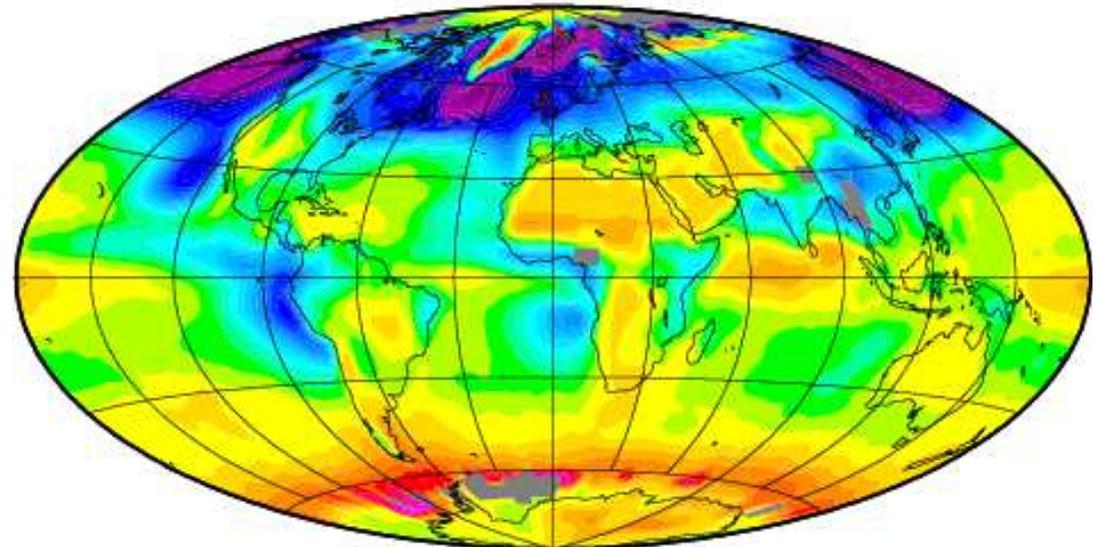
Dec-Jan-Fév



Net Radiative Cloud Forcing  
JJA 1985-1986

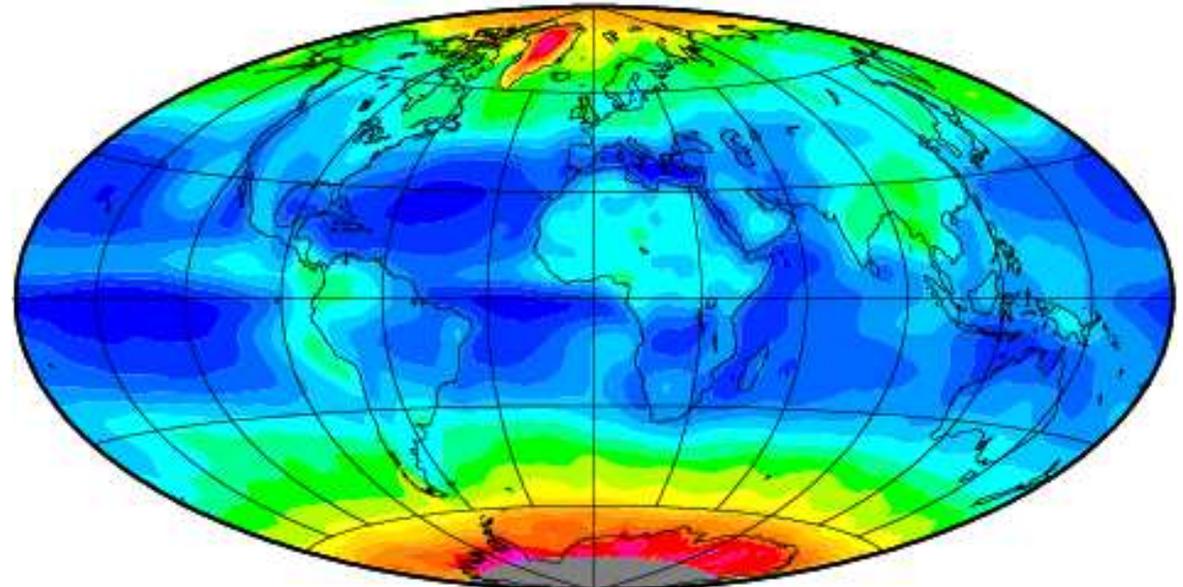
# Forçage radiatif net des nuages

Juin-Juil-août



W/m<sup>2</sup>

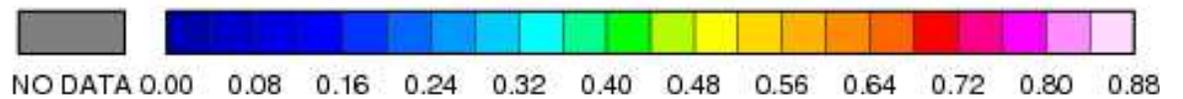
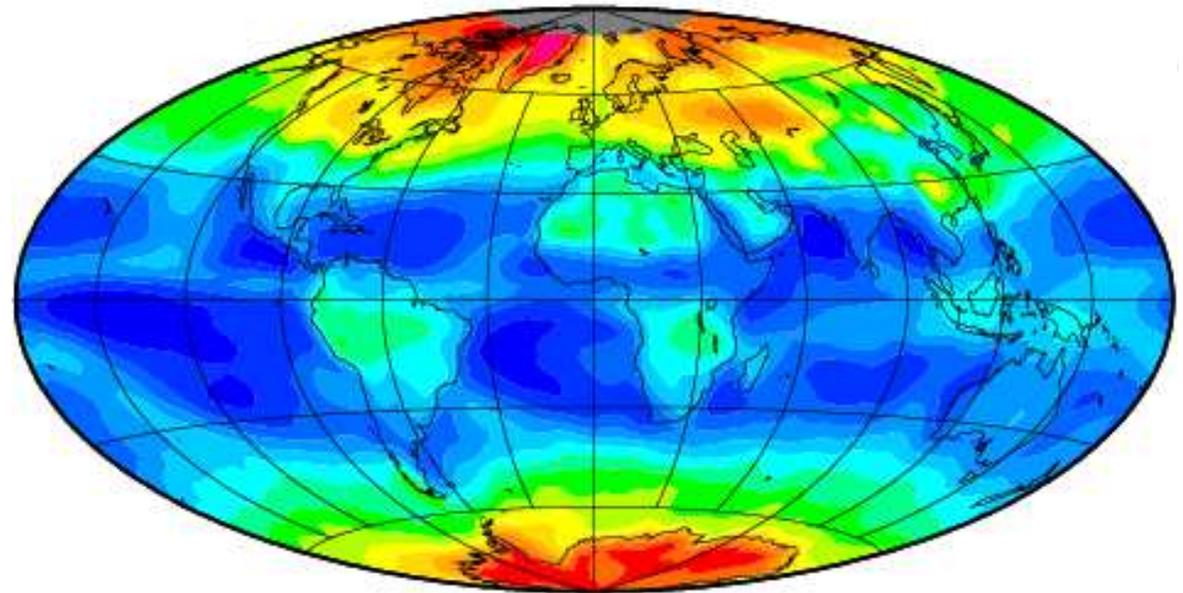
Dec-Jan-Fev



Albedo

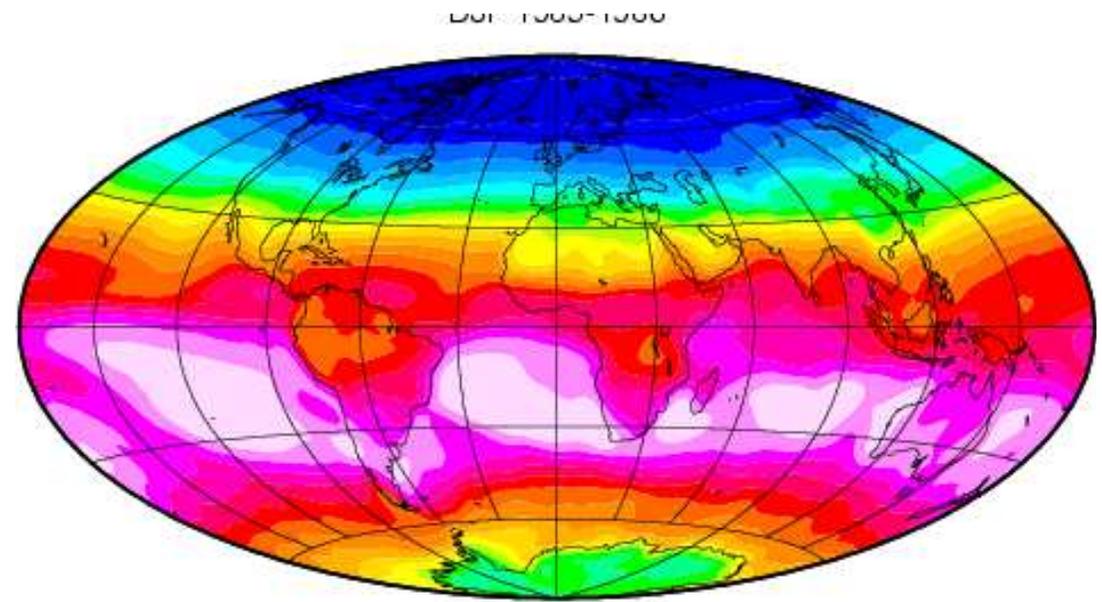
Albedo  
DJF 1985-1986

Juin-Juil-Août



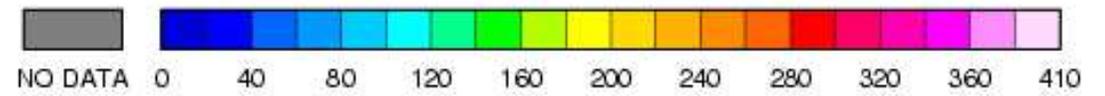
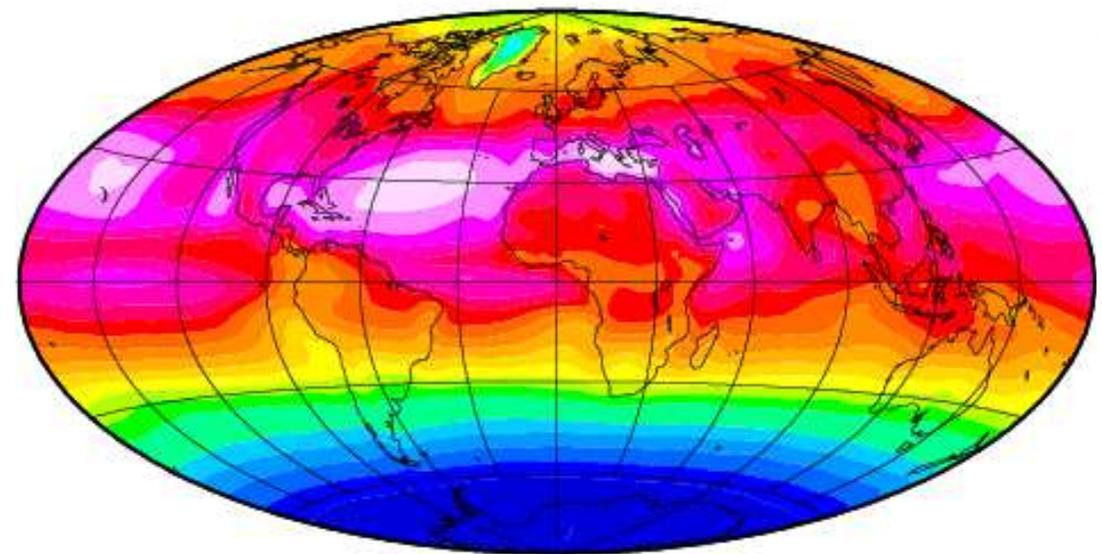
Dec-Jan-Fév

Rayonnement  
Visible absorbé

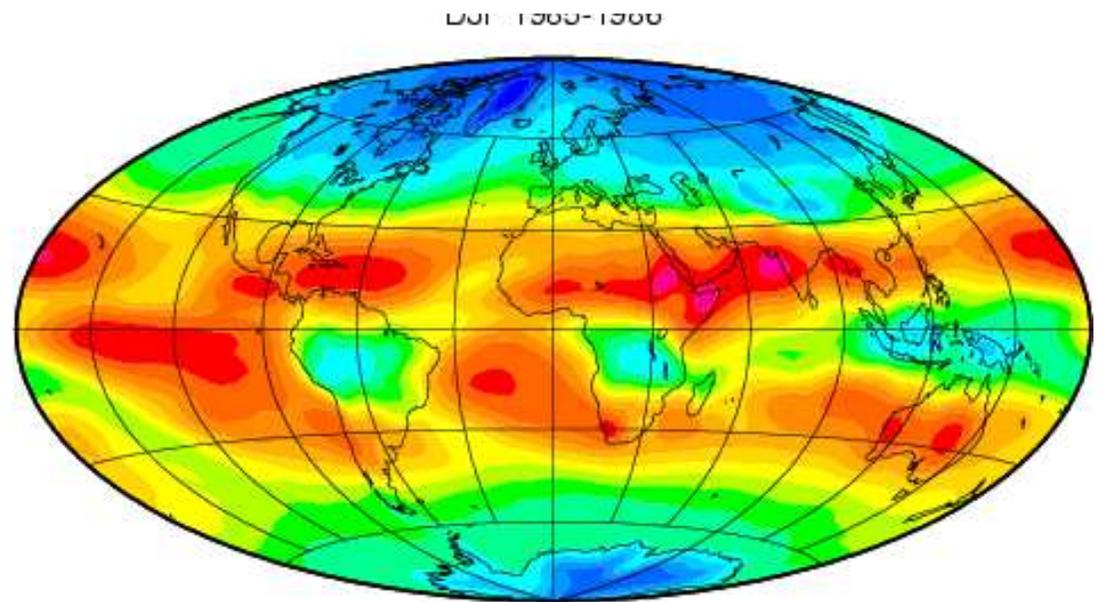


Absorbed Shortwave Radiation  
JJA 1985-1986

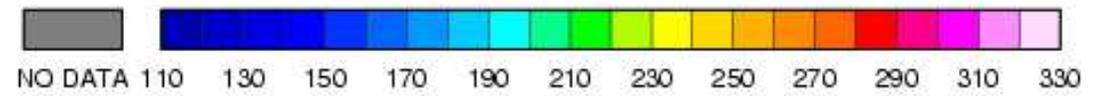
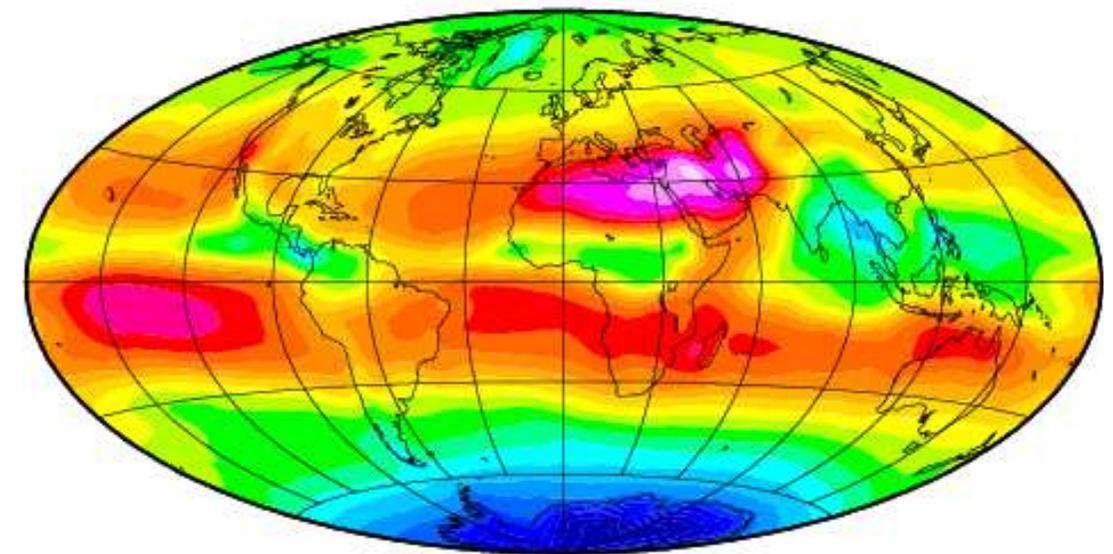
Juin-Juil-Août



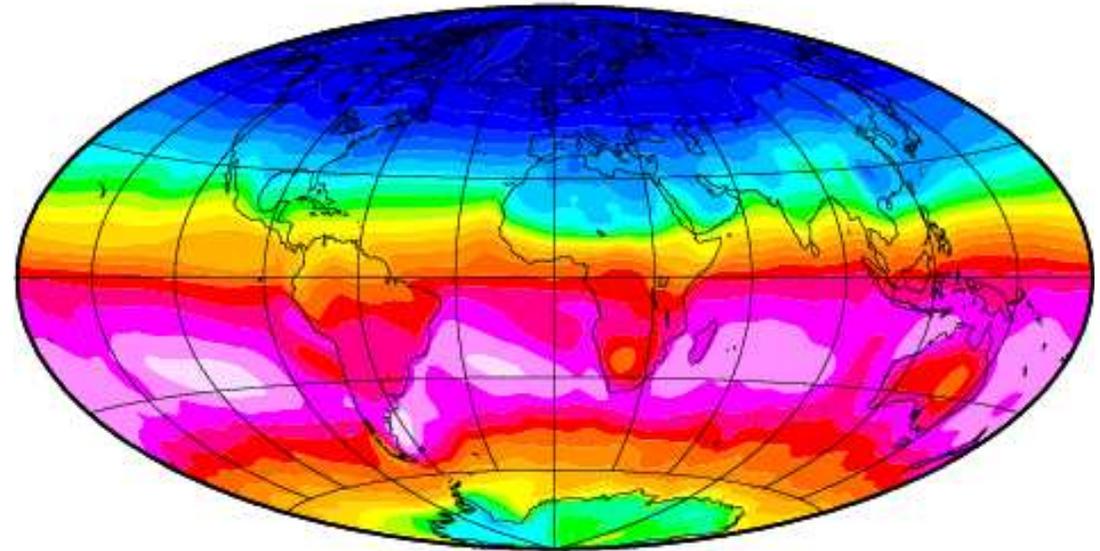
Dec-Jan-Fév  
Rayonnement  
Infrarouge sortant



Outgoing Longwave Radiation  
JJA 1985-1986



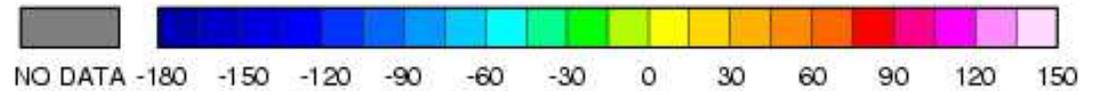
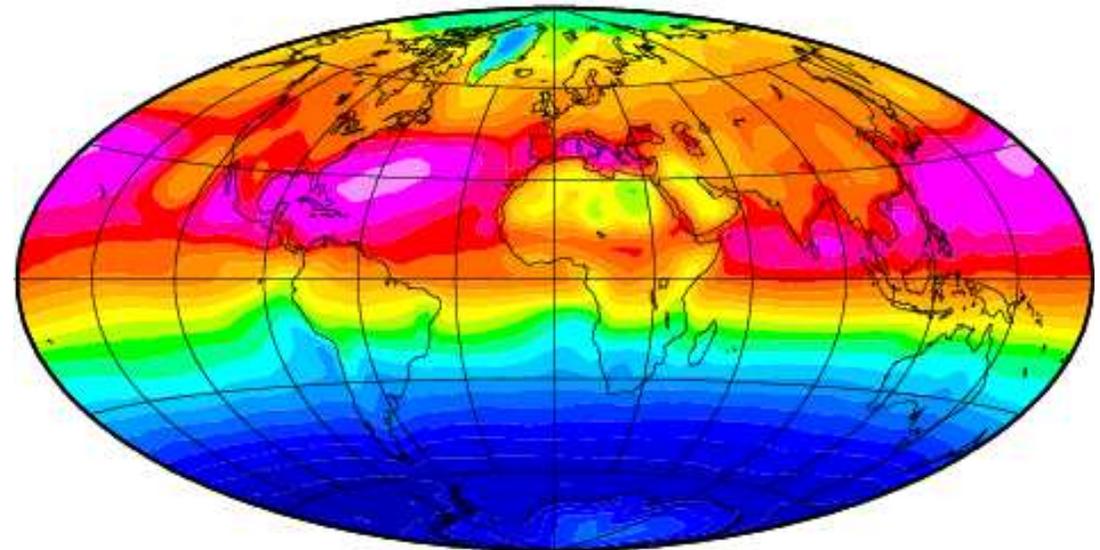
Dec-Jan-Fév



# Rayonnement Net

Net Radiation  
JJA 1985-1986

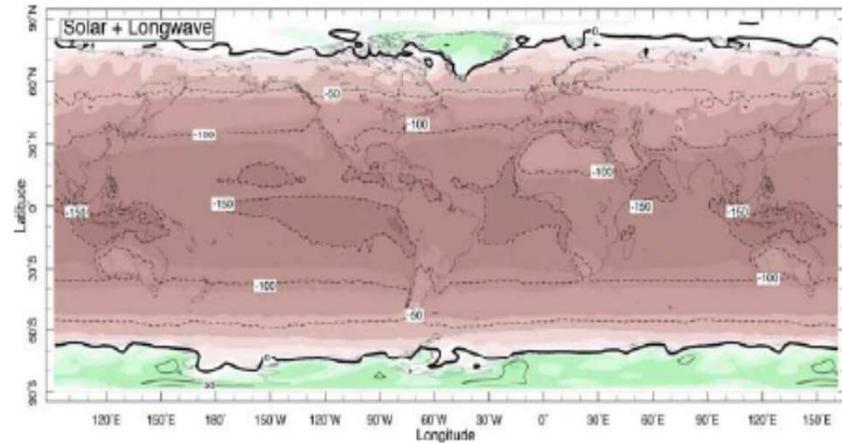
Juin-Juil-Août



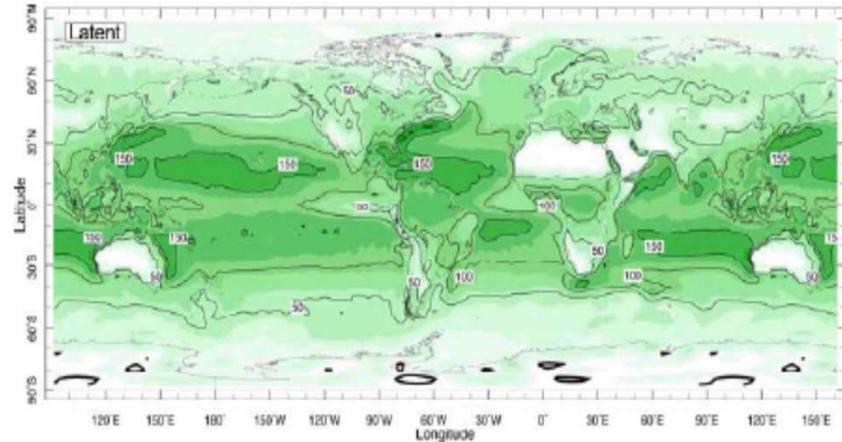
# Flux de chaleur Surface->atmosphère

➤ Gains radiatif et pertes turbulentes en surface, sauf régions polaires.

Radiatif



Latent



Sensible

