$$B_\lambda(T) = \frac{2hc^2}{\lambda^5\left[e^{\frac{hc}{\lambda kT}} - 1\right]}$$

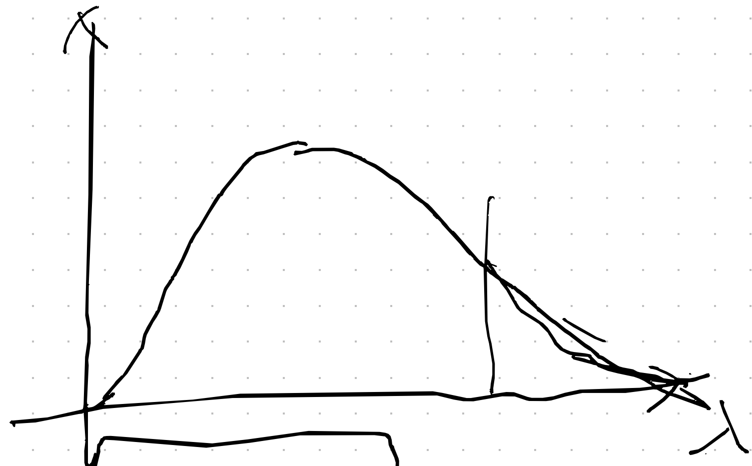
Brightness temperature

$\lambda \rightarrow$

c

h

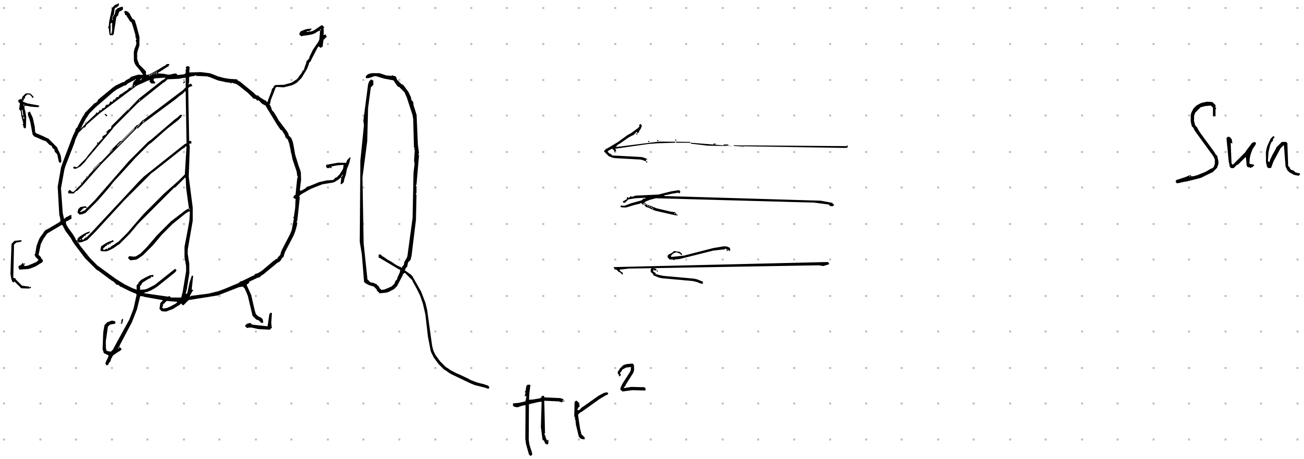
k



$$\int B_\lambda(T)\, d\lambda = \frac{2\pi^5 k^4}{15 c^2 h^3} T^4 = \sigma T^4$$

$$\sigma = 5.67 \cdot 10^{-8}\ W/m^2/K^4$$

$$B_\lambda(T) = f(T)$$



$$S_0 = 1370 \ W/m^2$$

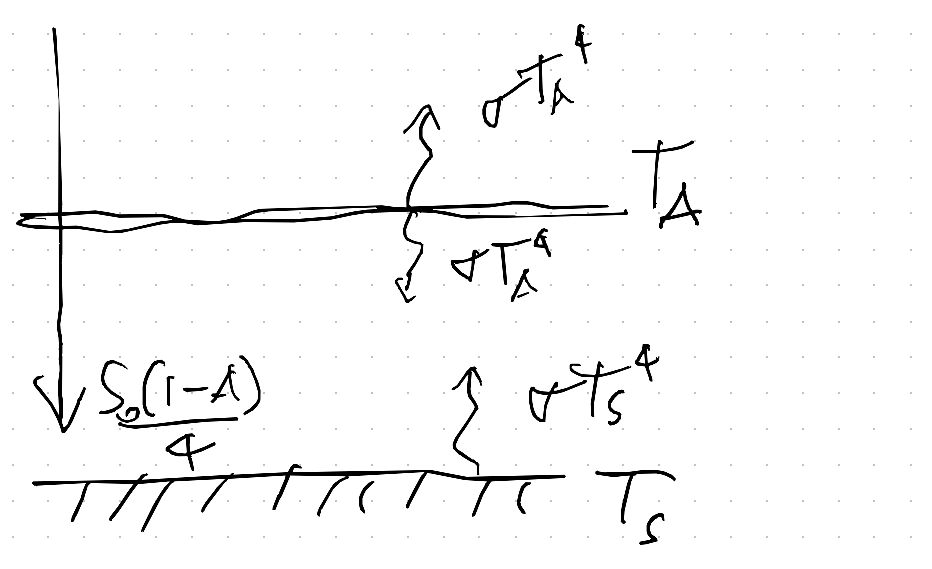
$$S_0 \cancel{\pi r^2} (1 - A) = \sigma T_e^4 \cancel{4\pi r^2}$$

A ↑ 0.3

$$T_e^4 = \frac{S_0(1-A)}{4\sigma}$$

$$T_e = \sqrt[4]{\frac{S_0(1-A)}{4\sigma}} = 255 \ K$$

$$\frac{S_0 \pi r^2 (1-A)}{4\pi r^2} = \frac{S_0(1-A)}{4}$$



TOP $\frac{S_o(1-A)}{4} = \sigma T_A^4$ $T_A = 255\ K$

Surface $\frac{S_o(1-A)}{4} + \sigma T_A^4 = \sigma T_s^4$ ←

at A $\sigma T_s^4 = 2\sigma T_A^4$

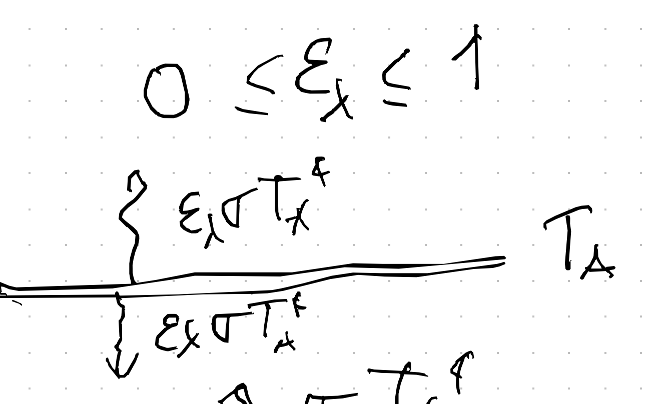
$$\frac{S_o(1-A)}{4} + \frac{1}{2}\sigma T_s^4 = \sigma T_s^4$$

$$\frac{S_o(1-A)}{4} = \frac{1}{2}\sigma T_s^4$$

$$T_s = \sqrt[4]{\frac{S_o(1-A)}{2\sigma}} \simeq 303\ K$$

$$B_{\lambda,g}(T) = \frac{\varepsilon_\lambda h c^2}{\lambda^5 \left[e^{\frac{hc}{\lambda k T}} - 1\right]}$$

$$0 \le \varepsilon_\lambda \le 1$$



$\varepsilon_\lambda, a_\lambda$

$t = (1 - a_\lambda) = 1 - \varepsilon_\lambda$

$$T_s^4 = \frac{S_o(1-A)}{4\sigma\left(1 - \frac{\varepsilon}{2}\right)}$$ < 255 K, 303 K

$$\varepsilon \sigma T_A^4 = \frac{\varepsilon S_o(1-A)}{8\left(1 - \varepsilon/2\right)} = LW\downarrow$$

Radiative Forcing

$$\Delta F_{TOA} = \left[R\downarrow_{TOA} - R\uparrow_{TOA}\right]_{2\times CO_2} - \left[R\downarrow_{TOA} - R\uparrow_{TOA}\right]$$ ↓ >0 ↑ <0

IR $R\downarrow$

$$\Delta F_{TOA} = -R\uparrow_{TOA\,2CO_2} + R\uparrow_{TOA} = +4\ W/m^2$$

$R\uparrow = \sigma T^4$

$\Delta R\uparrow = 4T^3\sigma\,\Delta T$

$$\boxed{\frac{\Delta T}{\Delta R\uparrow} = \frac{1}{4\sigma T^3}}$$

$$\frac{\Delta T}{\Delta R\uparrow} \simeq 0{,}25\ °C/W/m^2$$

$\Delta R\uparrow \sim 4\ W/m^2$

$\Delta T \to 1\ °C$

$dx = K x\, dt$

$\frac{dx}{x} = k\, dt$ $\ln x = kt$

$$\boxed{x = x_0 e^{kt}}$$

SW = SW (Clouds, aerosol, ice, ...)

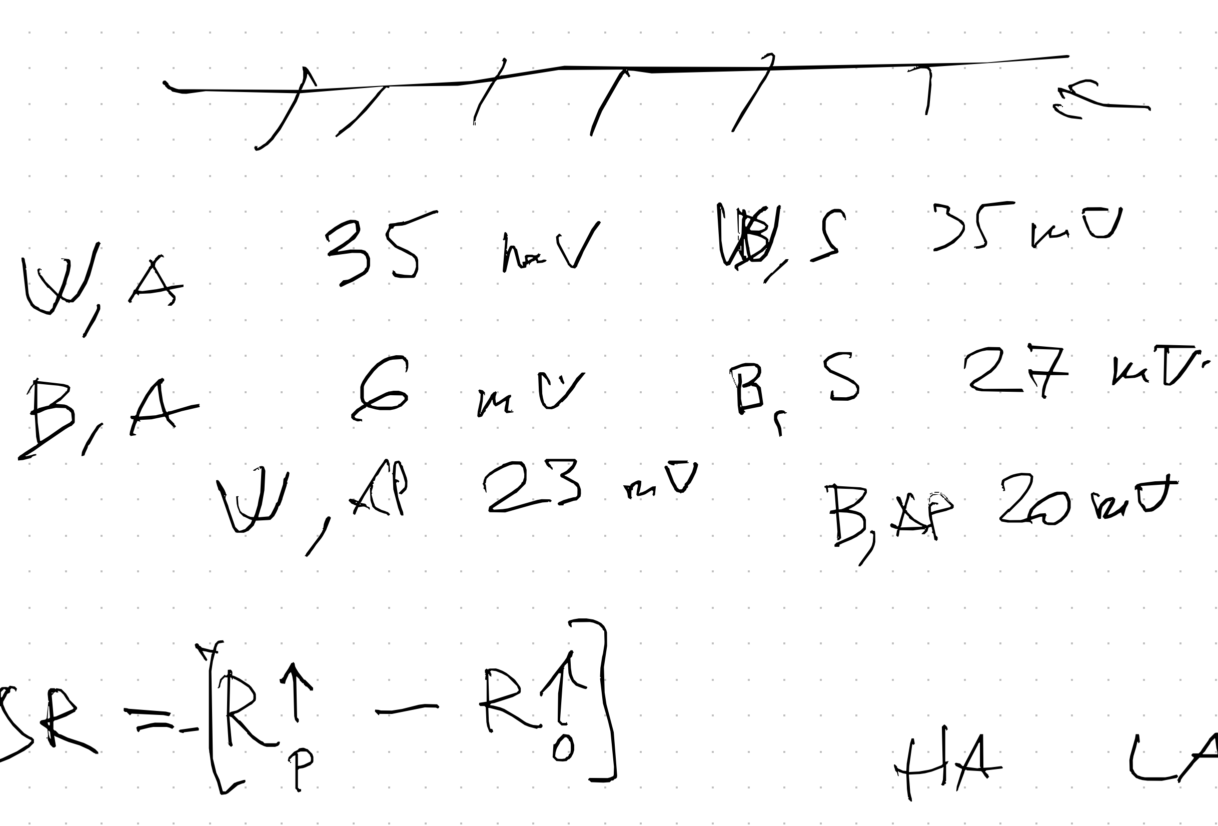
LW = LW(T, CO_2, clouds, aerosol, ...)

x

$$\frac{dT_s}{dx} = \frac{\partial T_s}{\partial x} + \sum_{1}^{N} \frac{\partial T_s}{\partial y_i}\frac{\partial y_i}{\partial x}$$

$$\frac{dT}{d\log_2 CO_2} = \frac{\frac{\partial T_s}{\partial \log_2 CO_2}}{1 - f}$$

$$\frac{\Delta T_f}{\Delta T} = \frac{1}{1 - f}$$ f>0, f<0



W, A 35 mV W, S 35 mV

B, A 6 mV B, S 27 mV

W, AP 23 mV B, AP 20 mV

$$\Delta R = -\left[R\uparrow_p - R\uparrow_0\right]$$ HA LA

P1 Scattering aerosol

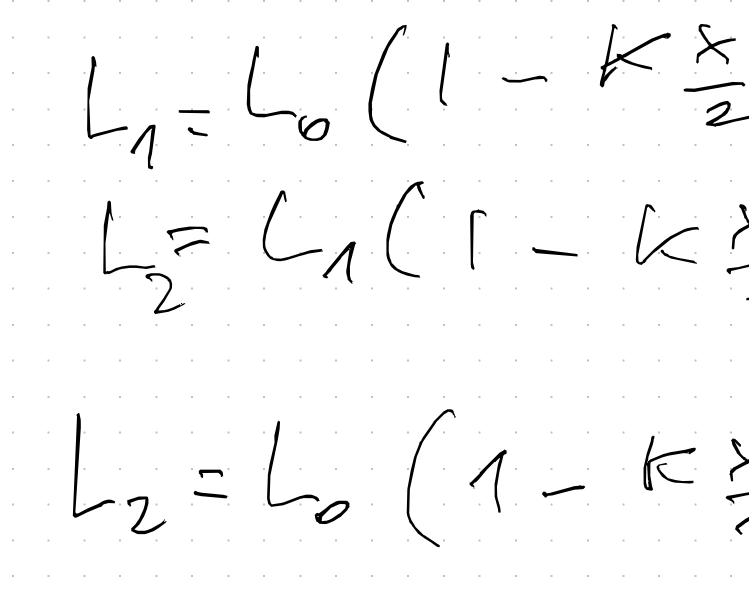
P2 absorbing aerosol

HA, P1 $\Delta R = 0$ mV

LA, P1 $\Delta R = -21$ mV

HA, P2 $\Delta R = -\{23 - 35\} = +12$ mV

LA, P2 $\Delta R = -(20 - 23) = +3$ mV



$L_0 - L_1 = k L_0 x$

$L_1 = L_0(1 - kx)$

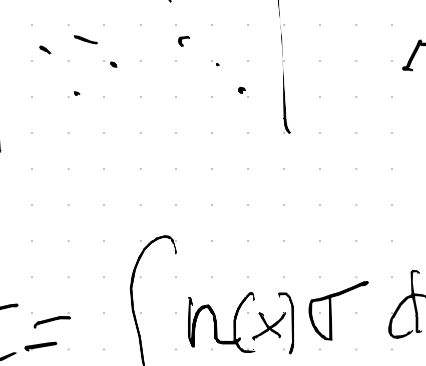
$L_1 = L_0\left(1 - k\frac{x}{2}\right)$

$L_2 = L_1\left(1 - k\frac{x}{2}\right)$

$L_2 = L_0\left(1 - k\frac{x}{2}\right)^2$ extinction coefficient

$L_n = L_0\left(1 - k\frac{x}{n}\right)^n$ ↗ $kx = \tau$ ↙ optical depth

$$\lim_{n\to\infty} L_n = L_0 e^{-kx}$$



$\tau = kx$ $\tau = \int k\, dx$

$\tau = \int n(x)\sigma\, dx$ $k = n\sigma$ $[k] = [m^{-1}]$ $[\sigma] = [m^2]$

$L = L_0 e^{-\tau}$ $\tau = \ln\frac{L_0}{L}$

$$\tau = \ln \frac{L_0}{L}$$

$$\tau = \tau_{abs} + \tau_{scatt}$$