(1) Global warming presentation

(2) Last time

$$\frac{dI_\eta}{ds} = -(K_{a\eta}+K_{s\eta})I_\eta + K_{a\eta} I_{b\eta} + \frac{K_{s\eta}}{4\pi}\int_{4\pi} \Phi(\Omega'\to\Omega)\, I_\eta'(\Omega')d\Omega'$$

or

$$\hat{e}_\Omega \cdot \nabla I_\eta = -(K_{a\eta}+K_{s\eta}) I_\eta + K_{a\eta} I_{b\eta} + \frac{K_{s\eta}}{4\pi}\int_{4\pi} \Phi(\Omega'\to\Omega)\, I_\eta'(\Omega')d\Omega'$$

$$d\tau_\eta = (K_{a\eta}+K_{s\eta})ds$$

$$\frac{dI_\eta}{d\tau_\eta} = -I_\eta + \underbrace{(1-\omega_\eta)I_{b\eta} + \frac{\omega_\eta}{4\pi}\int \Phi(\Omega'\to\Omega) I_\eta'(\Omega')d\Omega'}_{S_\eta(\tau_\eta,\hat{\Omega})}$$

$$\frac{dI_\eta}{d\tau_\eta} = -I_\eta + S_\eta$$

(1) Historic trend / human factors / evidence. 2

(2) How much solar radiati is absorbed by earth 2

factors : gas
particles
land
sea.

(3) How much earth radiati escapes 3

gas
particles
land
sea

(4) What happens if earth temperat rise by $\underline{1}$°C, $\underline{5}$°C ?

$$I_\lambda = \frac{|\vec{v}|}{4\pi}\cdot \hbar\omega \cdot f$$

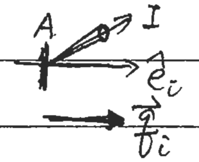
$$\frac{dI_\lambda}{ds} = \frac{dI_\lambda}{d\vec{r}}\cdot\frac{d\vec{r}}{ds} = \hat{e}_\Omega \cdot \nabla I_r$$

Radiative flux

$$I_\lambda = \frac{P_\lambda}{\Delta A_\perp \Delta\Omega \Delta\lambda}$$

$$P_\lambda = I_\lambda \Delta A_\perp \Delta\Omega \Delta\lambda$$

$$= I_\lambda \cos\theta \, \Delta\Omega \Delta\lambda A$$



$$q_i = \int_0^\infty \int_{4\pi} \frac{P_\lambda \cancel{\cos\theta}}{\cancel{\Delta} A} d\Omega \, d\lambda$$

$$= \int_0^\infty d\lambda \int_{4\pi} I_\lambda \cos\theta \, d\Omega$$

$$= \int_0^\infty \oint_{4\pi} I_\lambda \, \hat{e}_\Omega \cdot \hat{e}_i \, d\Omega.$$

$$\vec{q} = q_x \hat{e}_x + q_y \hat{e}_y + q_z \hat{e}_z$$

~~Rad~~ heat generat' due to absorpt'

$$\dot{q} = -\nabla\cdot\vec{q}$$

radiat' equilibri $\nabla\cdot\vec{q} = 0$

if without medi Navier-Stokes equations : source term

Optical depth

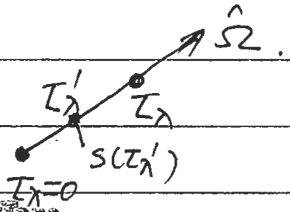
$$d\tau_\lambda = (k_{a\lambda} + k_{s\lambda})\,ds$$

$$\tau_\lambda = \int_0^s (k_{a\lambda} + k_{s\lambda})\,ds$$

albedo $\omega_\lambda = \frac{k_{s\lambda}}{k_{a\lambda} + k_{s\lambda}}$

⇒

$$\frac{dI_\lambda}{d\tau_\lambda} = -I_\lambda + \underbrace{(1-\omega_\lambda) I_{b\lambda} + \frac{\omega_\lambda}{4\pi}\int \Phi_\lambda(\Omega' \to \Omega)}_{\text{Source function } S_\lambda(\tau_\lambda, \hat{\Omega})} I_\lambda \, d\Omega'$$



$$\frac{d(I_\lambda e^{\tau_\lambda})}{d\tau_\lambda} = S_\lambda e^{\tau_\lambda}$$

$$I_\lambda(\tau_\lambda) = I_\lambda(0) e^{-\tau_\lambda} + \int_0^{\tau_\lambda} S_\lambda(\tau_\lambda', \hat{\Omega}) e^{-(\tau_\lambda - \tau_\lambda')} d\tau_\lambda'$$

explain terminology: ballistic
nonlocal.

If there is no scattering

$$S_\lambda = I_{b\lambda}$$

$$\Downarrow$$

$$I_\lambda(\tau_\lambda) = I_\lambda(0)e^{-\tau_\lambda} + \int_0^{\tau_\lambda} I_{b\lambda}(\tau_\lambda')e^{-(\tau_\lambda-\tau_\lambda')}d\tau_\lambda'$$

Cold medium $I_{b\lambda} \approx 0$

$$I_\lambda(\tau_\lambda) = I_\lambda(0)e^{-\tau_\lambda} + \int_0^{\tau_\lambda} \frac{\omega_\lambda}{4\pi} \int_{4\pi} I_\lambda(\tau_\lambda', \hat{\Omega}')\Phi(\Omega' \to \Omega)\, d\Omega\, e^{-(\tau_\lambda-\tau_\lambda')} d\tau_\lambda'$$

Isotropic scattering $\Phi_\lambda = 1$

$$I_\lambda(\tau_\lambda) = I_\lambda(0)e^{-\tau_\lambda} + \frac{1}{4\pi}\int_0^{\tau_\lambda} \omega_\lambda G_\lambda(\tau_\lambda')e^{-(\tau_\lambda-\tau_\lambda')}d\tau_\lambda'$$

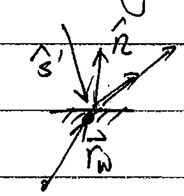
$$G_\lambda(\tau) \equiv \int_{4\pi} I_\lambda(\tau_\lambda', \hat{\Omega}')\, d\Omega$$

↑ total intensity impinging on a point.

local energy density $u_\lambda = \frac{G_\lambda}{c}$ $\cancel{4\pi}$

purely scattering $\omega_\lambda = 1$.

Boundary Conditions: Intensity made of two parts: reflection + emission



$\cancel{I(\vec{r}_w, \hat{s})/\pi}$

diffuse: $I(\vec{r}_w, \hat{s}) = \epsilon(\vec{r}_w) I_b(\vec{r}_w) + \rho(\vec{r}_w) H(\vec{r}_w)/\pi$

↑ Hemisph. irradiation

$$= \epsilon(\vec{r}_w) I_b(\vec{r}_w) + \frac{\rho(\vec{r}_w)}{\pi}\int_{\hat{n}\cdot\hat{s}'<0} I(\vec{r}_w, \hat{s}')\,|\hat{n}\cdot\hat{s}'|\, d\Omega'$$

1815

Diffusely emitting, specularly reflecting, ~~partially~~ partially diffuse reflecting

$$I(\vec{r}_w,\hat{s}) = \epsilon(\vec{r}_w) I_b(\vec{r}_w) + \frac{\rho^d(\vec{r}_w)}{\pi}\int_{\hat{n}\cdot\hat{s}'} I(\vec{r}_w,\hat{s}')\,|\hat{n}\cdot\hat{s}'|\,d\Omega'$$

$$+ \rho^s(\vec{r}_w)\, I(\vec{r}_w,\hat{s}_s)$$

Specify intensity for 4π directions

~~Radiat equ~~ Isotropic scattering

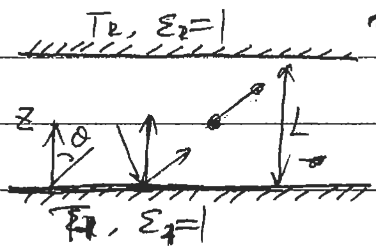
$$\frac{dI_\lambda}{d\tau_{o\lambda}} = -I_\lambda + (1-\omega_\lambda) I_{b\lambda} + \omega_\lambda I_\lambda$$

$$\tau_\lambda = (K_{s\lambda} + K_{a\lambda}) s$$

$$\frac{dI_\lambda}{ds} = -K_{a\lambda} I_\lambda + K_{a\lambda} I_{b\lambda}$$

$$\cos\theta \frac{dI_\lambda}{dz} = -K_{a\lambda} I_\lambda + K_{a\lambda} I_{b\lambda} \qquad \mu = \cos\theta \text{ directional cosine}$$

$$\tau = K_{a\lambda} z \qquad \text{b.C: } 4\pi$$



$\tau = 0$

$$I_\lambda = \frac{E_{b\lambda}(T_1)}{\pi} = I_{b1} \qquad 0 < \theta < 90$$

$$0 < \varphi < 2\pi$$

$\tau = L$:

$$I_\lambda = \frac{E_{b\lambda}(T_2)}{\pi}.$$

$$I_\lambda^+(\tau,\mu) = I_{\lambda b1}\, e^{-\frac{\tau}{\cos\theta}} + \int_0^{\tau} I_{b\lambda}(\tau')\, e^{-\frac{(\tau-\tau')}{\mu}} \frac{d\tau'}{\mu}$$

$$0 < \mu < 1$$

$$I_\lambda^-(\tau,\mu) = I_{\lambda b2}\, e^{+\frac{(\tau_L-\tau)}{\mu}} + \int_{\tau_L}^{\tau} I_{b\lambda}(\tau')\, e^{+\frac{(\tau'-\tau)}{\mu}} \frac{d\tau'}{-\mu}$$

$$= I_{\lambda b2}\, e^{\frac{\tau_L-\tau}{\mu}} + \int_{\tau}^{\tau_L} I_{b\lambda}(\tau')\, e^{\frac{(\tau'-\tau)}{\mu}} \frac{d\tau'}{\mu}$$

$$-1 < \mu < 0.$$