1

Energy Balance Modeling — Feb 9, 2011

Review

I "zero dim"

Black body Planet

$F_{in} = F_{out}$

net SW = net LW

$$(1-\alpha)\frac{S_\odot}{4} = \sigma T_s^4$$

* all quantities are globally averaged

$$\lambda_B = \frac{\Delta Q}{\Delta T}$$

For example raise $S_\odot$ so F_{in} goes up instantaneously hence $\Delta Q = \Delta F_{in}$

Assuming α = const

planet warms so that $\Delta F_{OUT} = \Delta F_{in} = \Delta Q$

At equilibrium Energy balance is restored and planet warms by ΔT_s

$$F_{OUT}(T_s + \Delta T_s) = F_{OUT}(T_s) + \frac{\partial F_{out}}{\partial T_s}\Delta T_s + \Theta(\Delta T_s^2)$$

$$\Delta F_{OUT} = F_{OUT}(T_s + \Delta T) - F_{OUT}(T_s)$$

$$\approx \frac{\partial F_{OUT}}{\partial T_s}\Delta T_s = 4\sigma T_s^3 \Delta T_s$$

$$\lambda_B = 4\sigma T_s^3 = 3.75 \text{ W/m}^2\text{/K}$$

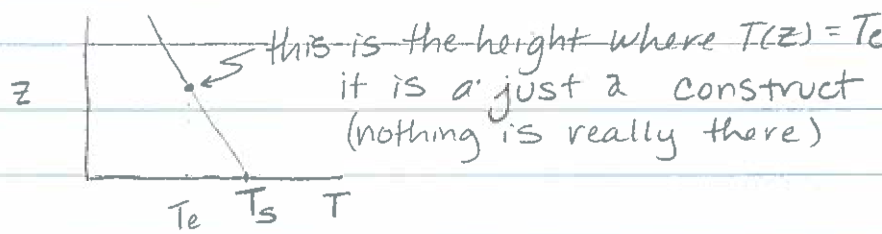
This FB is negative which is funny because $\lambda_B > 0$

Define $\Lambda_B = -\lambda_B$ called "Signed Feedback" by Boer & Hu 2003

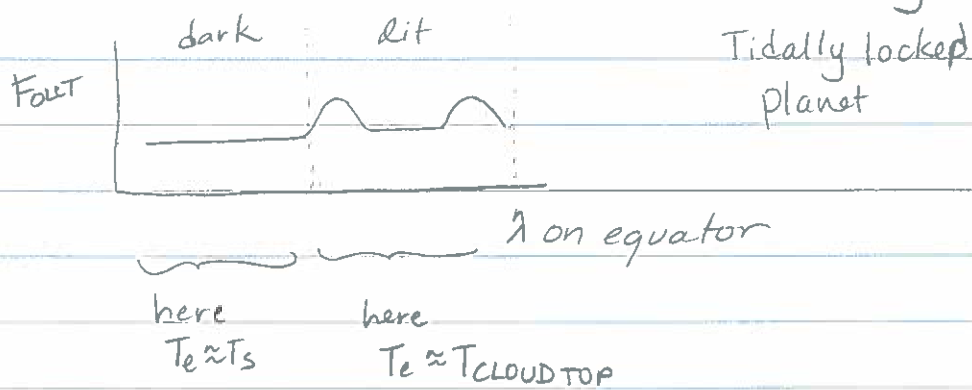
Planet w/ an atmosphere

$F_{OUT} = \sigma T_e^4$ solve for T_e "effective Temp"

and Find what height it occurs at in real atm.



However think back to class on Monday



Very cold atmosphere have very little greenhouse effect

③

Alternative approach

$F_{out} = \varepsilon \sigma T^4 \tau_a$

emissivity of surf — IR Transmissivity of Atm

$\varepsilon \tau_a \approx 0.62$

One-D (which is ϕ)

$\phi_i = i \Delta\phi_i$

note not uniform in ϕ

T_i = Temp of SURFACE at i

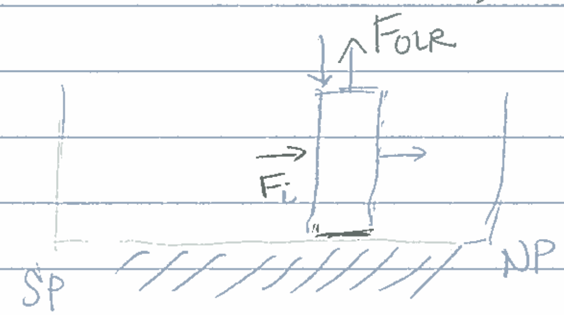
at Equilibrium

S_i = solar in at i

$\alpha_i(T_i) = \begin{cases} 0.6 & T_s < T_c \\ 0.3 & T_s > T_c \end{cases}$

$S_i(1-\alpha_i(T_i)) = F_{OLR}(T_i) + \nabla \cdot F_i$

absorbed SW — outgoing LW — divergence at side (sign corrected after class)



not necessary but it is traditional to $\varepsilon\sigma\sigma T_s^4 \approx A + BT_s$

Simplified Sellers Form

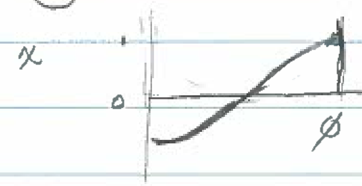
~~First continous~~

$\nabla \cdot F = \frac{-D}{\cos\phi} \frac{\partial}{\partial\phi} D\cos\phi \frac{\partial T}{\partial \phi}$ (Sign corrected after class)

Simplifying from p.88 of book which has an error anyway in eq 3.17 the last $T \to q(T)$

$$S_i(1-\alpha_i(T_i)) = A + BT_i - \frac{D}{\cos\phi_i}\frac{\partial}{\partial\phi}\Big|_{at\ \phi_i} D\cos\phi_i \frac{\partial T}{\partial\phi}\Big|_{at\ \phi_i}$$

traditionally let $x = \sin\phi$



magically

$$\frac{1}{\cos\phi}\frac{d}{d\phi} D\cos\phi \frac{d}{d\phi} \longrightarrow \frac{d}{dx} D(1-x^2)\frac{d}{dx}$$