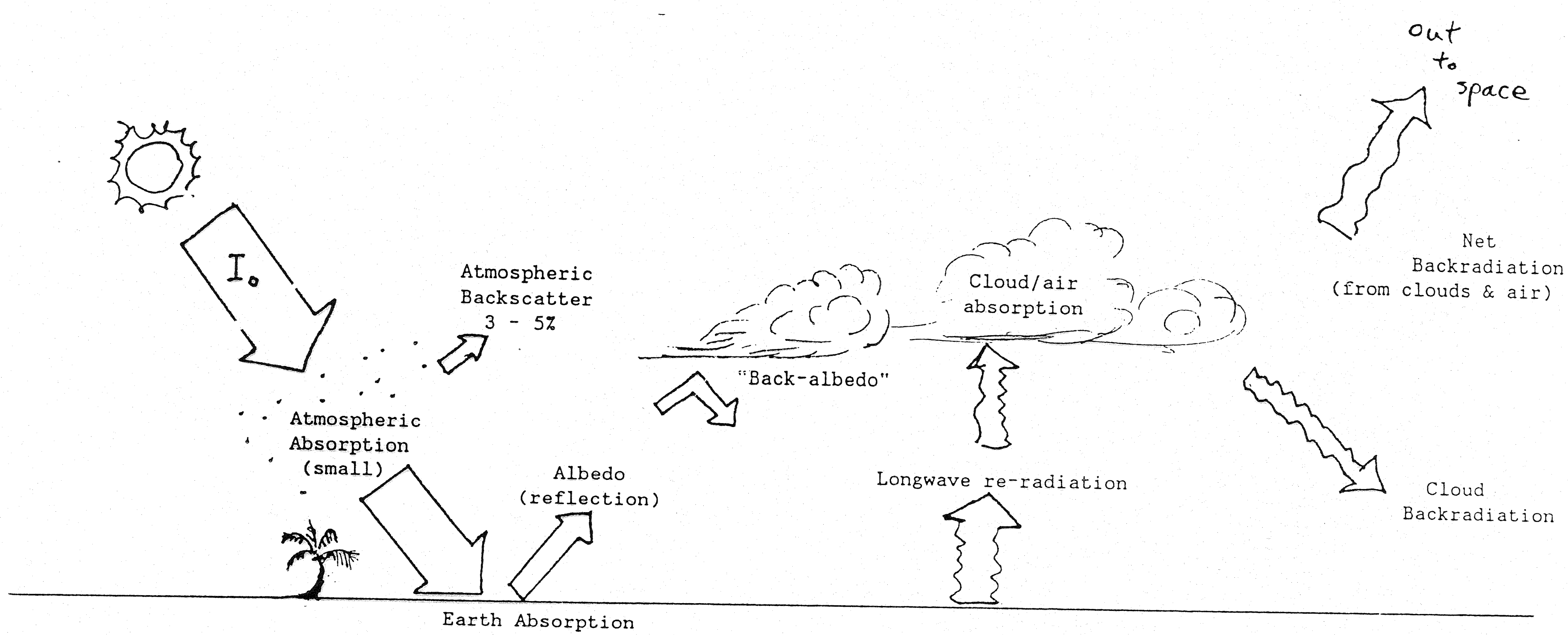
Energy Balance:

After light enters the lower atmosphere, it "bounces" around. ...

RADIATIVE ENERGY BALANCE IN THE LOWER ATMOSPHERE



A few important points:

Radiative Fluxes for a Water Body

SHORTWAVE = Visible light

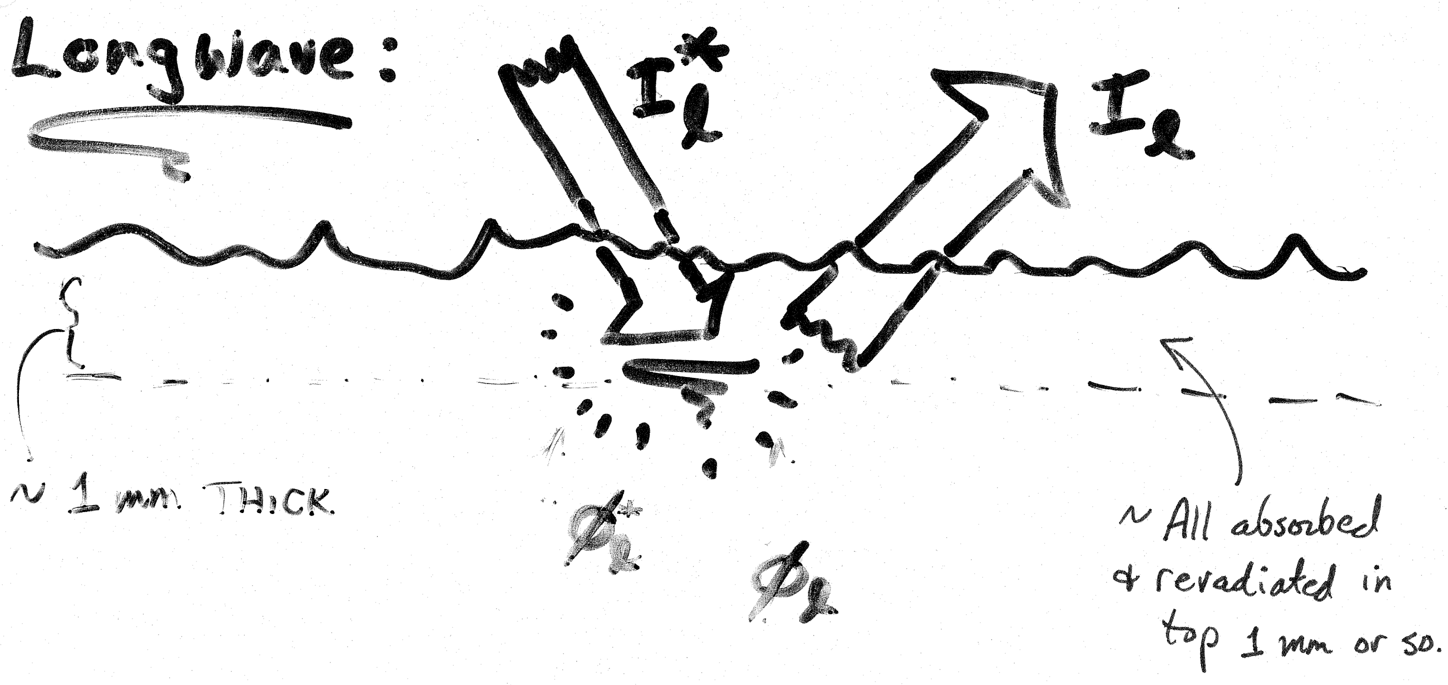
LONGWAVE = Infrared light

ϕ_s = Shortwave <u>in</u> = I_s^*

ϕ_ℓ^* = longwave <u>in</u> = I_ℓ^*

ϕ_ℓ = longwave <u>out</u> = I_ℓ

Longwave:



"OUT" = (+) > 0

"IN" = (−) < 0

TOTAL RADIATIVE INPUT

$$\phi_r = \phi_s + \phi_l + \phi_l^*$$

SHORT WAVE

LONG WAVE OUT

LONG WAVE IN

$\approx -1000 \ W \cdot m^{-2}$ (TYPICAL)

SUNNY DAY, NOON

$+400 \ W/m^2$

WARM WATER, CLOUDLESS NIGHT

Be careful about "NET"

- NET RADIATION FLUX
- NET HEAT FLUX

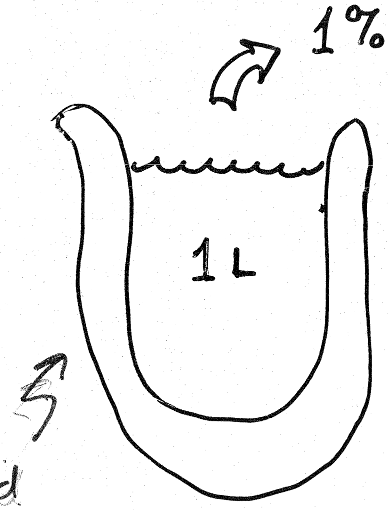
EVAPORATIVE FLUX OF LATENT HEAT

H_L = Latent heat of vaporization

For $H_2O \approx 2{,}400$ J/g

(near 20°C)

E.g.:



Thermal Energy = 24,000 J

≈ 5,500 cal

$\Delta T = 5.5$ °C

$T_1 = 20$°C → $T_2 = 14.5$°C

Or, to think another way

24,000 J = Energy of full tropical sunlight shining on the 10 cm x 10 cm surface for ~ 40 minutes

(∴ EVAP ≈ SOLAR HEATING)

EVAPORATION: Key, but can't measure directly

∴ Relate heat loss (gain) to mass loss (gain)

$$\phi_{evap} = \phi_{\substack{mass\\evap}} \cdot H_L$$

TYPICAL RANGE:

$-100\ J\,m^{-2}\,s^{-1}$ (W/m^2) ~MAX. CONDENSATION

$+1000\ W/m^2$ ~MAX. EVAPORATION

But, problems with measurement

Instead, use

Empirical relationships:

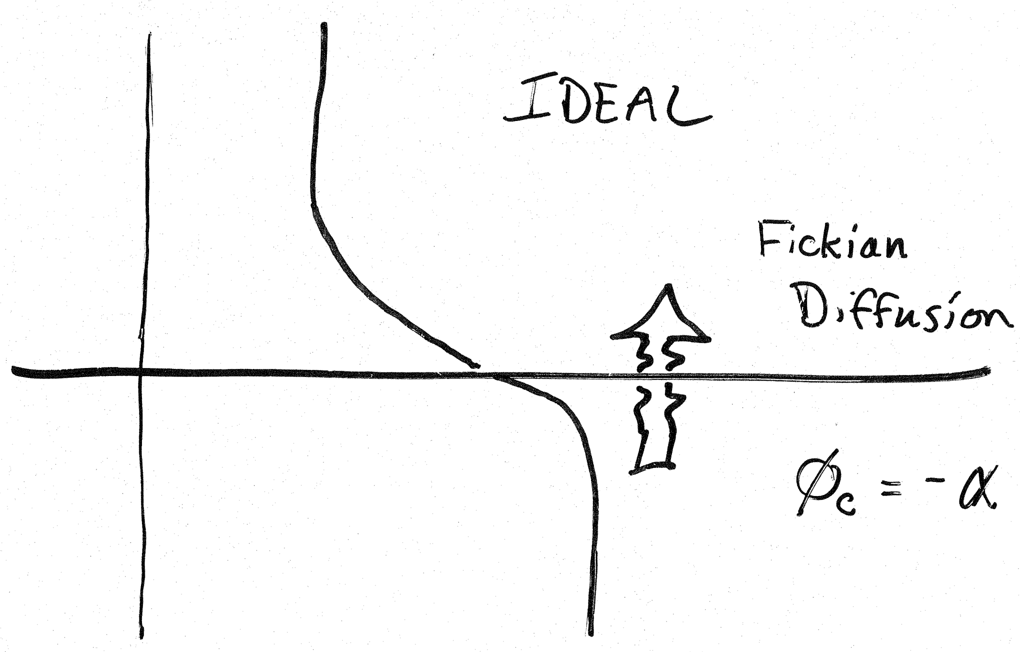
$$\phi_e \approx H_L K_e (\rho_{vs} - \rho_{va})$$

ρ_s = sat'd vapor density at $T = T_{surf}$

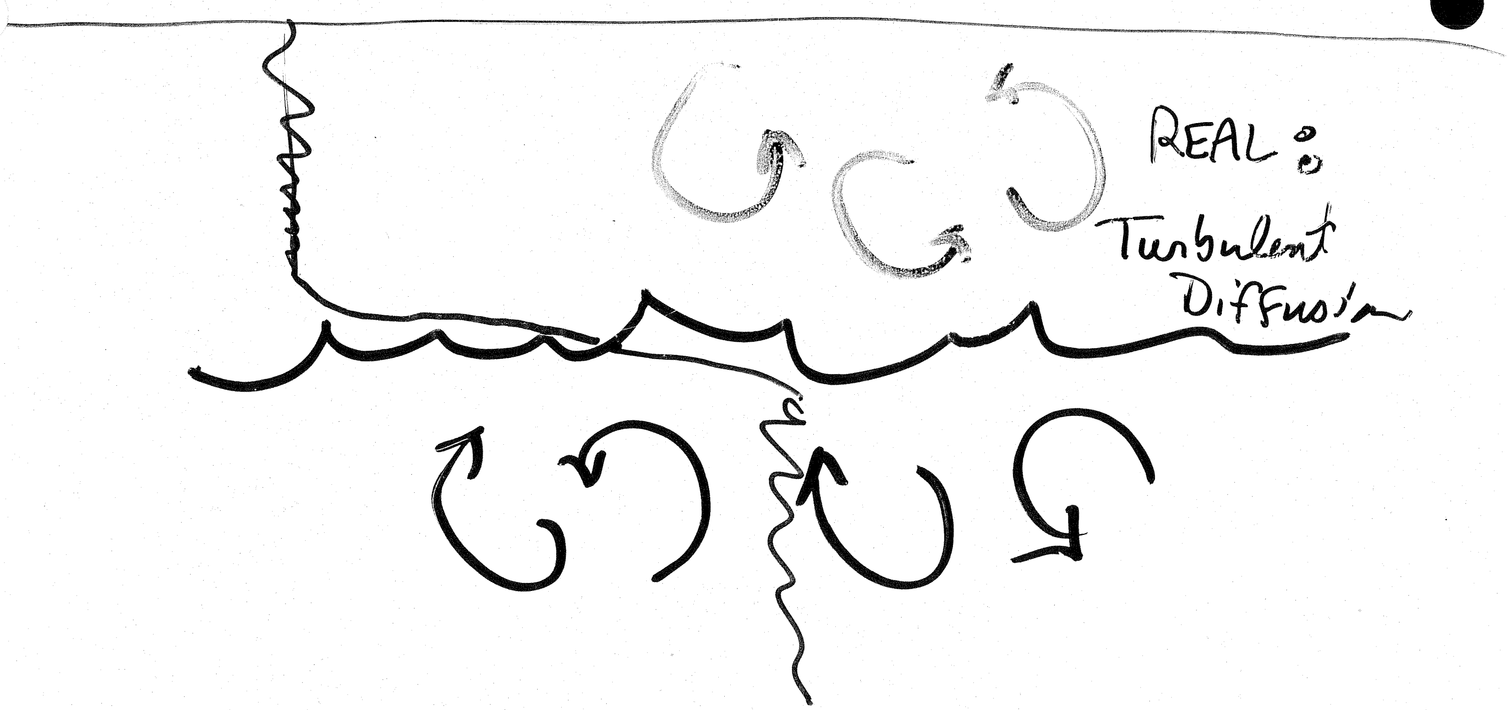
ρ_a = vapor density in air at ref. height

K_e = empirical bulk transfer coeff.

CONDUCTION



$$\phi_c = -\alpha \frac{dT}{dz}$$



$$\phi_c = -K_H \frac{\Delta T}{\Delta z} \qquad \Delta T \,? \qquad \Delta z \,?$$

EMPIRICAL

$$\phi_c = \rho_a C_{pa} K_c (T_s - T_a)$$

CONDUCTION
(Sensible Heat Flux)

BOWEN RATIO:

$$\phi_c = R\,\phi_e$$

↑ CALCULATE/MEASURE ϕ_e

↑ Determine R

$$R = C_\ell \left| \frac{T_s - T_z}{e_s - e_z} \right|$$

$$C_1 = 61.0\ \mathrm{Pa}/^{o}\mathrm{C}$$

NET HEAT FLUX

$$\phi_{net} = \phi_e + \phi_c + \phi_\ell$$

$$= \phi_e + \phi_c + \phi_s^* + \phi_\ell + \phi_\ell^*$$

$$= \boxed{\phi_e + \phi_c + \phi_\ell} + \boxed{\phi_s^* + \phi_\ell^*}$$

T_s - Dependence Astronomical

⇑ **FEEDBACK** ⇑ **"FORCING"**

$$\phi_{net}[T_s] = \phi_T(T_s) + \text{Constant}$$