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

\[ \phi_s = \text{Shortwave in} = I_s^* \]

\[ \phi_l^* = \text{Longwave in} = I_l^* \]

\[ \phi_l = \text{Longwave out} = I_l \]

Longwave:

\[ I_l^* \]

\[ I_l \]

\[ I_l \]

\[ \phi_s \]

\[ \phi_l \]

\[ \approx 1 \text{ mm thick} \]

\[ \sim \text{All absorbed and reemitted in top 1 mm or so.} \]

"Out" = (+) > 0

"In" = (-) < 0
Total Radiative Input

\[ \Phi_r = \Phi_s + \Phi_l + \Phi_l^* \]

- Short Wave
- Long Wave Out
- Long Wave In

\[ -1000 \text{ W} \cdot \text{m}^{-2} \] (Typical)
Sunny Day, Noon

+ 400 \text{ W} \cdot \text{m}^{-2}
Warm Water, Cloudless Night

Be careful about "NET"
- NET RADIATION FLUX
- NET HEAT FLUX
**Evaporative Flux of Latent Heat**

\[ H_L = \text{Latent heat of vaporization} \]

For \( H_2O \approx 2,400 \text{ J/g} \)
(near 20°C)

**E.g.:**

\[ 1\% \ (= 10 \text{ g}) \]

\[ \text{Insulated} \]
\[ \text{Container} \]
\[ \text{"adiabatic"} \]

\[ \text{\( \Delta T = 5.5°C \)} \]

\[ T_1 = 20°C \rightarrow T_2 = 14.5°C \]

Or, to think another way

\[ 24,000 \text{ J} = \text{Energy of full tropical sunlight shining on the 10 cm x 10 cm surface for \sim 40 minutes} \]
EVAPORATION: Key, but can't measure directly

- Relate heat loss to mass loss (gain)

\[ \phi_{\text{evap}} = \phi_{\text{mass}} \cdot H_L \]

**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:

\[ \phi_e = H_L K_e (\rho_s - \rho_v) \]

- \(\rho_s\) = sat'd vapor density at \(T = T_{\text{surf}}\)
- \(\rho_v\) = vapor density in air at ref. height
- \(K_e\) = empirical bulk transfer coeff.
CONDUCTION

IDEAL

Fickian Diffusion

\[ \dot{\phi}_c = -\alpha \frac{dT}{dz} \]

REAL

Turbulent Diffusion

\[ \dot{\phi}_c = -K \frac{\Delta T}{\Delta z} \quad \Delta T? \quad \Delta z? \]

EMPIRICAL

\[ \dot{\phi}_c = \rho a C_{pa} k_c (T_s - T_a) \]
CONDUCTION
(Sensible Heat Flux)

Bowen Ratio:

\[ \phi_c = R \phi_e \]

\[ R = C_t \left| \frac{T_s - T_2}{e_s - e_a} \right| \]

\[ C_t = 61.0 \text{ Pa/}^\circ\text{C} \]
NET NEAT FLUX

\[ \phi_{\text{net}} = \phi_e + \phi_c + \phi_r \]

\[ = \phi_e + \phi_c + \phi_s^* + \phi_l + \phi_l^* \]

\[ = [\phi_e + \phi_c + \phi_l] + [\phi_s^* + \phi_l^*] \]

\( T_s \) - Dependence  

Astronomical

↑  

Feedback  

↑  

"Forcing"

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