ET Theory 101

USCID Workshop

http://biomet.ucdavis.edu

PMhr, PMday, PMmon

CUP, SIMETAW (DWR link)

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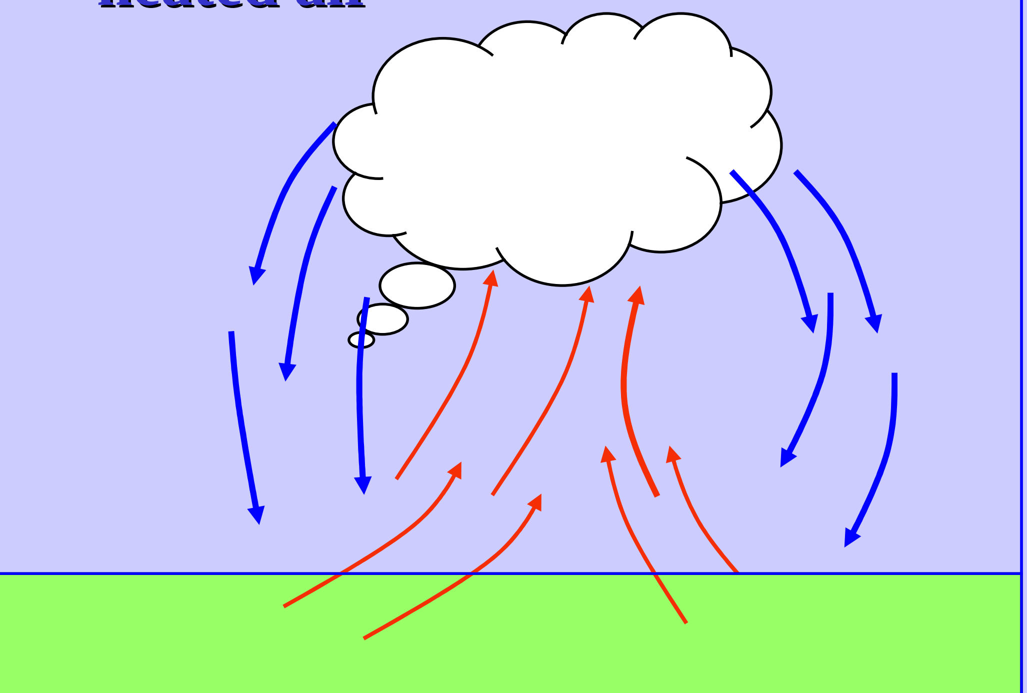
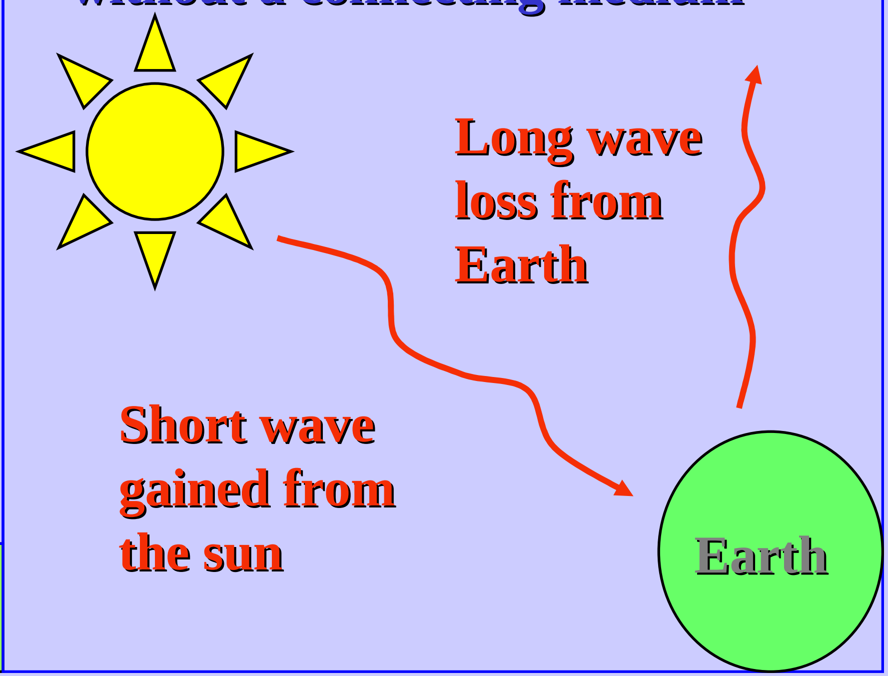
Methods of Heat Transfer

Conduction- from molecule to molecule

Convection – by movement of heated air



Radiation - energy passing from one object to another without a connecting medium



Questions 1 and 2

1. **How many molecules of air are in a cubic meter?**

   2.69×10^{25}

1. **If six billion people count 1000 molecules per hour, it would take 511 million years to count the number of molecules in 1 m^3**

26,900,000,000,000,000,000,000,000 molecules m^{-3}

2. **The air is mostly nitrogen? (T/F)?**

   False

2. **Air is mostly empty space. Less than 0.1% of the volume is occupied by molecules**

Horstmeyer, S. 2001. *Weatherwise* 54:20-27.

Questions 3 and 4

3. **Which molecules move faster?**
   A. nitrogen
   B. oxygen
   C. carbon dioxide
   D. water vapor

4. **When saturated, the air cannot hold more water vapor (T/F)?**

3. **At 30ºC, velocities**
   N_2 - 1709 Km h^{-1}
   O_2 - 1603 Km h^{-1}
   CO_2 - 1366 Km h^{-1}
   H_2O - 2136 Km h^{-1}

4. **False! Less than 0.1% of volume is occupied. Air can hold more water.**

Horstmeyer, S. 2001. *Weatherwise* 54:20-27.

Questions 5

5. **How many molecule collisions per second occur in a m^3 of air?**

5. **There are about 595 trillion collisions per second between air molecules in a m^3 of air.**

26,900,000,000,000,000,000,000,000 molecules m^{-3}

Occupy < 0.1% volume

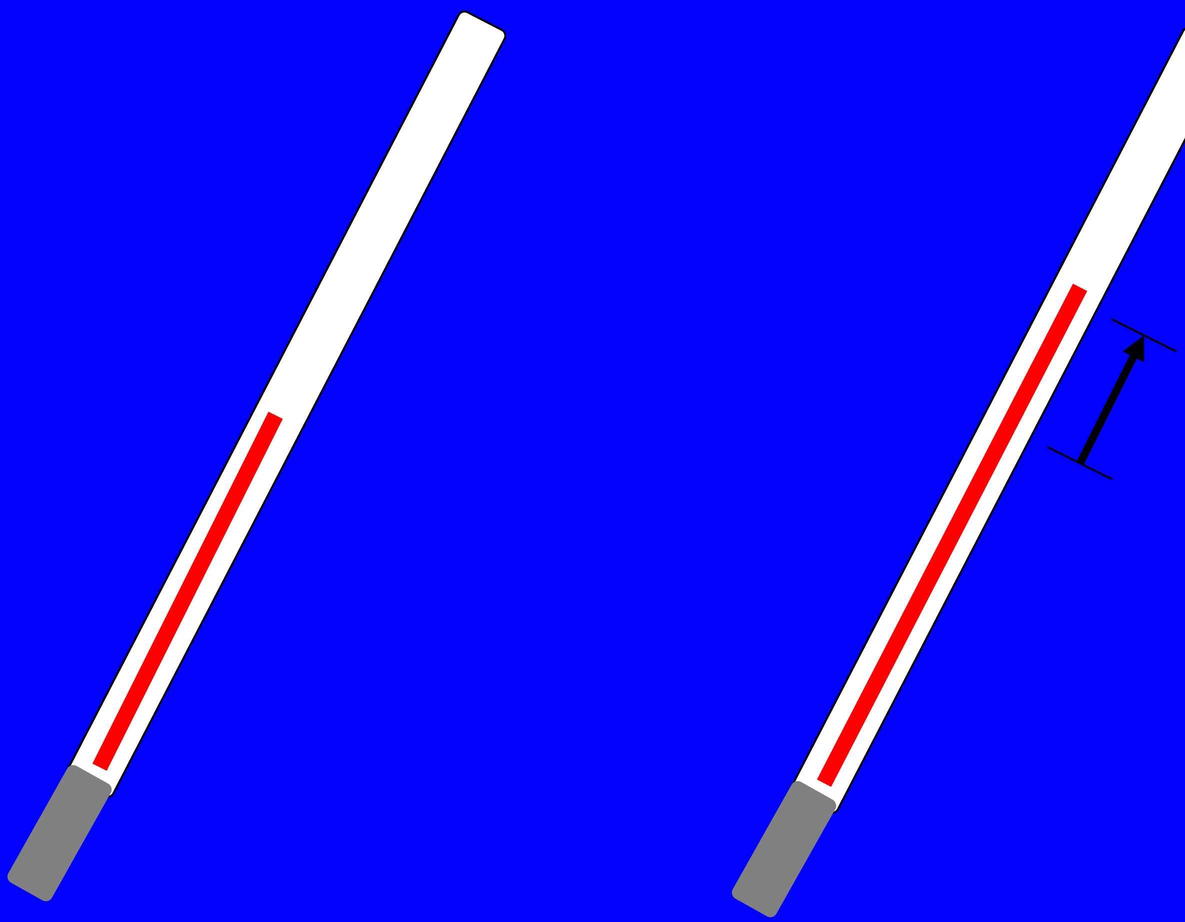
595,000,000,000,000 collisions/sec

Horstmeyer, S. 2001. *Weatherwise* 54:20-27.

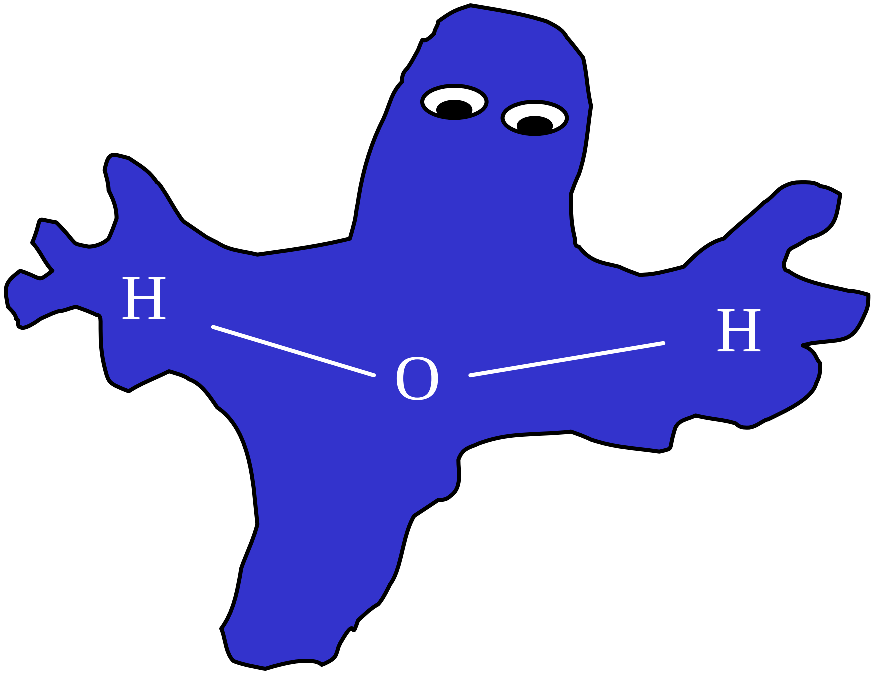
Sensible Heat & Temperature

Lower temperature
Less sensible heat

Higher temperature
More sensible heat

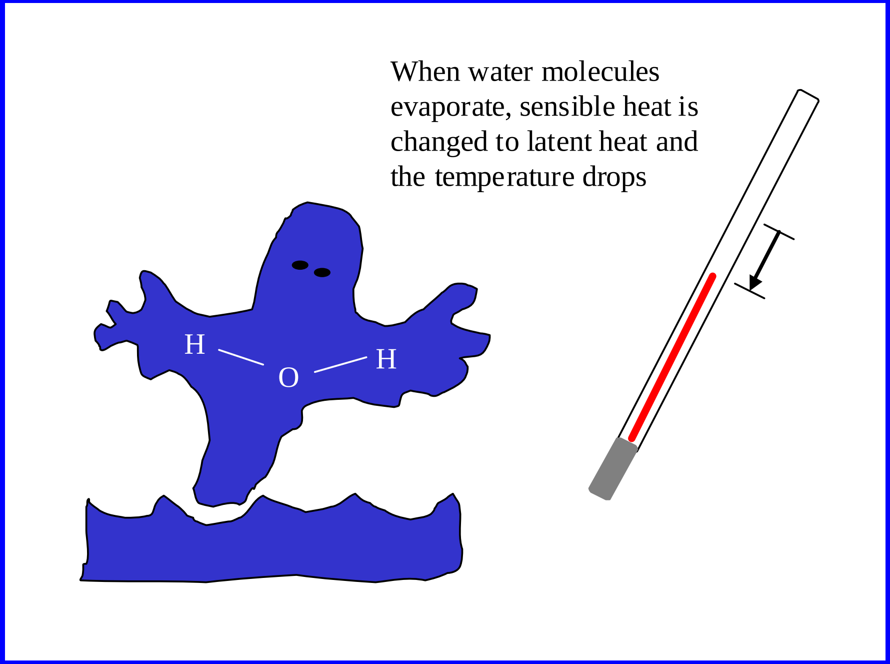


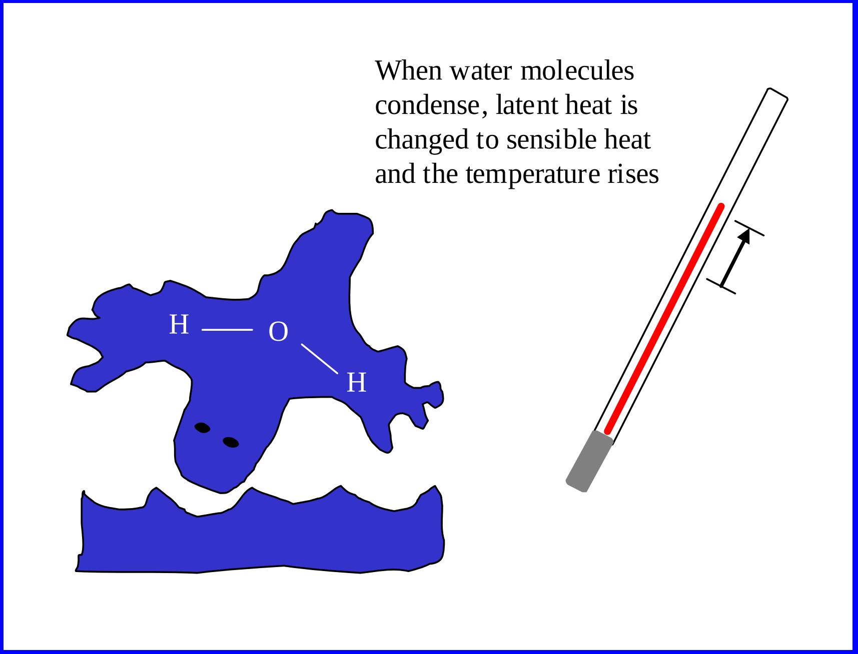
Water Molecules consist of one oxygen and two hydrogen atoms



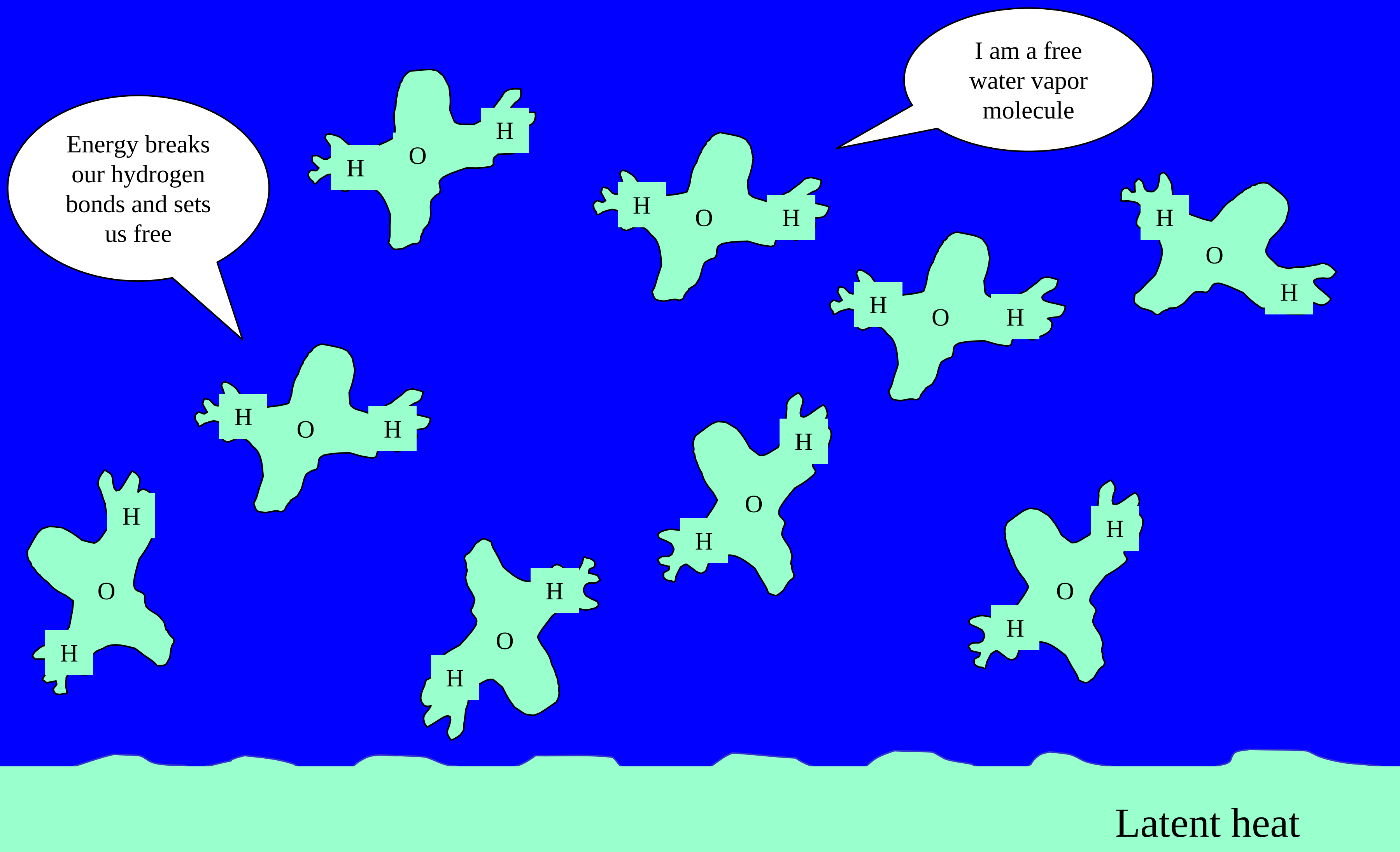
Methods of Heat Transfer

Latent Heat - Chemical Heat





More Water Vapor More Latent Heat



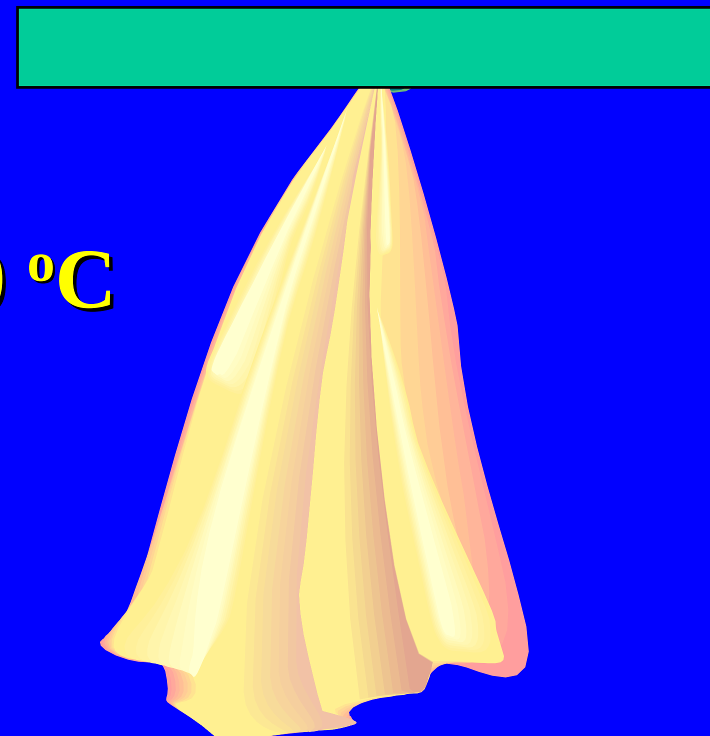
Questions 6

6. Your ice cream will melt faster at 35% RH than at 75% RH (T/F)?

6. False, there is more total heat in humid than in dry air to melt the ice cream

Which wet towel dries fastest?

T_a = 30 ºC



30 % RH

70 % RH

Adiabatic Process

Questions 7

7. **Is there evaporation in a greenhouse with 100% relative humidity?**

7. **Yes! But both the temperature and vapor pressure must increase following the saturation vapor pressure curve.**

Diabatic Process

Radiation

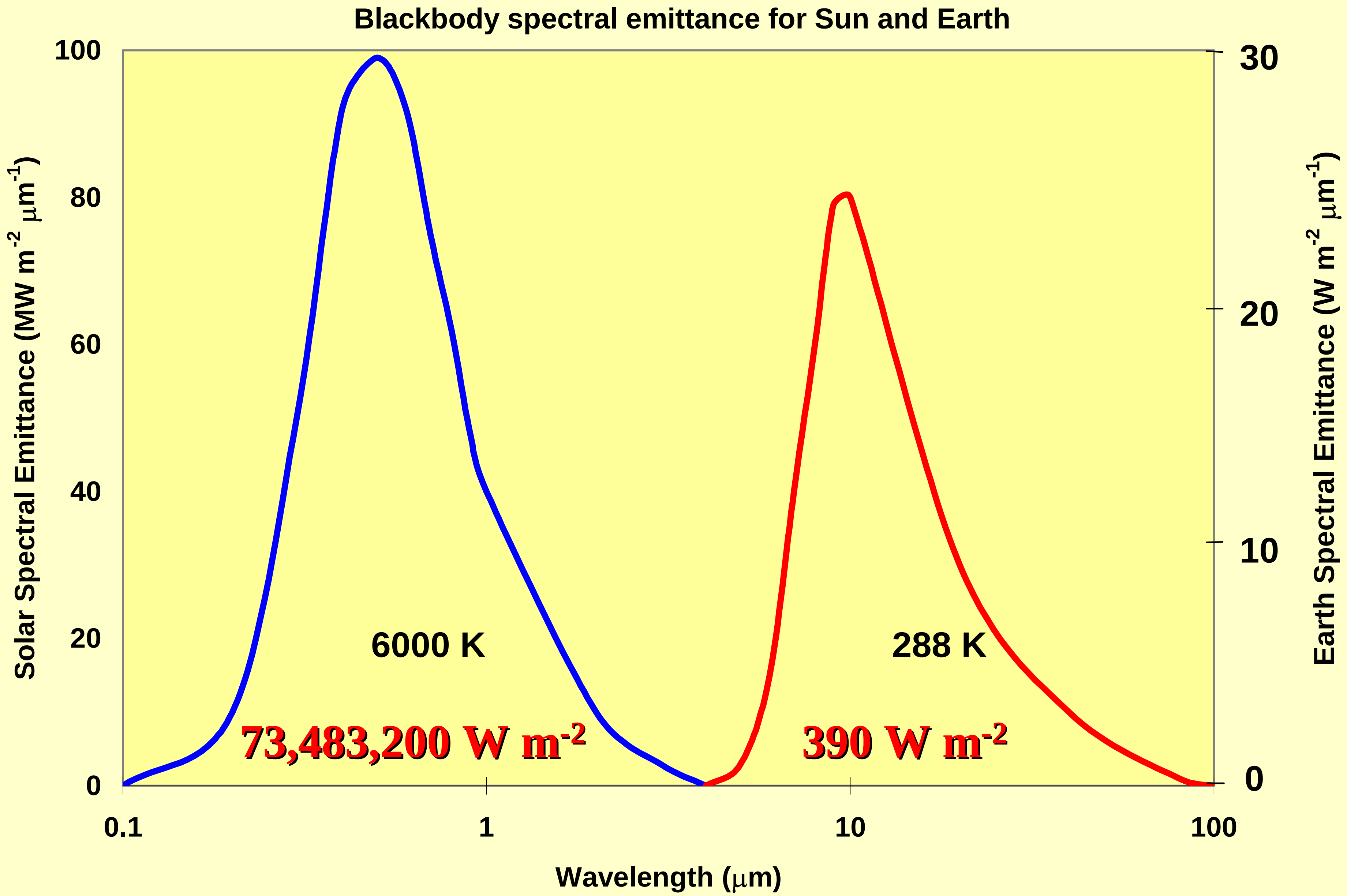
$$E = \varepsilon \sigma T^4$$

$\varepsilon = 1.0$ for a black body

$\varepsilon < 1.0$ for a gray body

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-1}

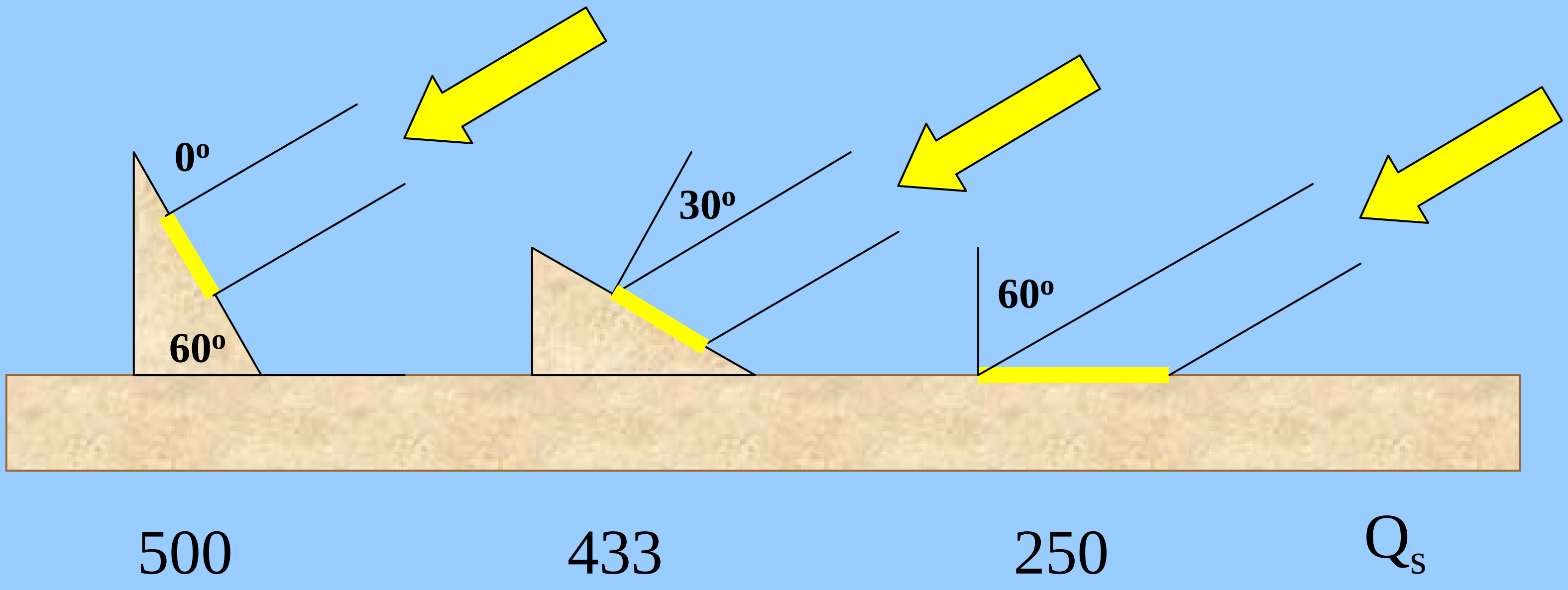
T = absolute temperature = ^{o}C+273.15


Blackbody spectral emittance for Sun and Earth
Solar Spectral Emittance (MW m-2 μm-1)
100
80
60
40
20
0
Earth Spectral Emittance (W m-2 μm-1)
30
20
10
0
6000 K
288 K
73,483,200 W m-2
390 W m-2
0.1
1
10
100
Wavelength (μm)

Direct Radiation (*Q*)

- Radiation that comes directly from the sun
- The amount of energy received per unit area is called "Irradiance" and the units are commonly $W\ m^{-2} = J\ s^{-1}\ m^{-2}$.
- The amount of energy received depends on the angle of incidence of the radiation

Direct beam radiation interception (W m^{-2})

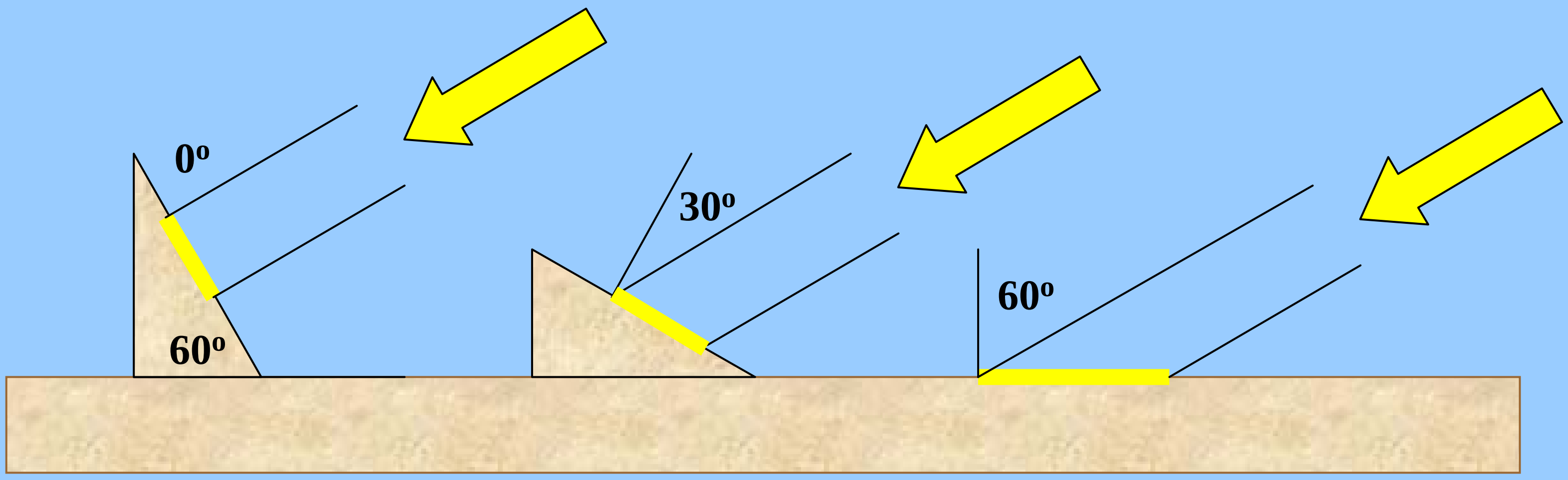


$$Q_s = Q \cos(\alpha)$$

Diffuse Radiation (*q*)

- Solar radiation that is scattered by the sky and comes from all directions.
- During much of the day, about 10 to 15% of the radiation received on a flat surface is diffuse radiation.
- The diffuse radiation is nearly the same regardless of the surface orientation.
- The percentage of diffuse radiation is higher near sunrise and sunset.

Direct and diffuse radiation (W m^{-2})

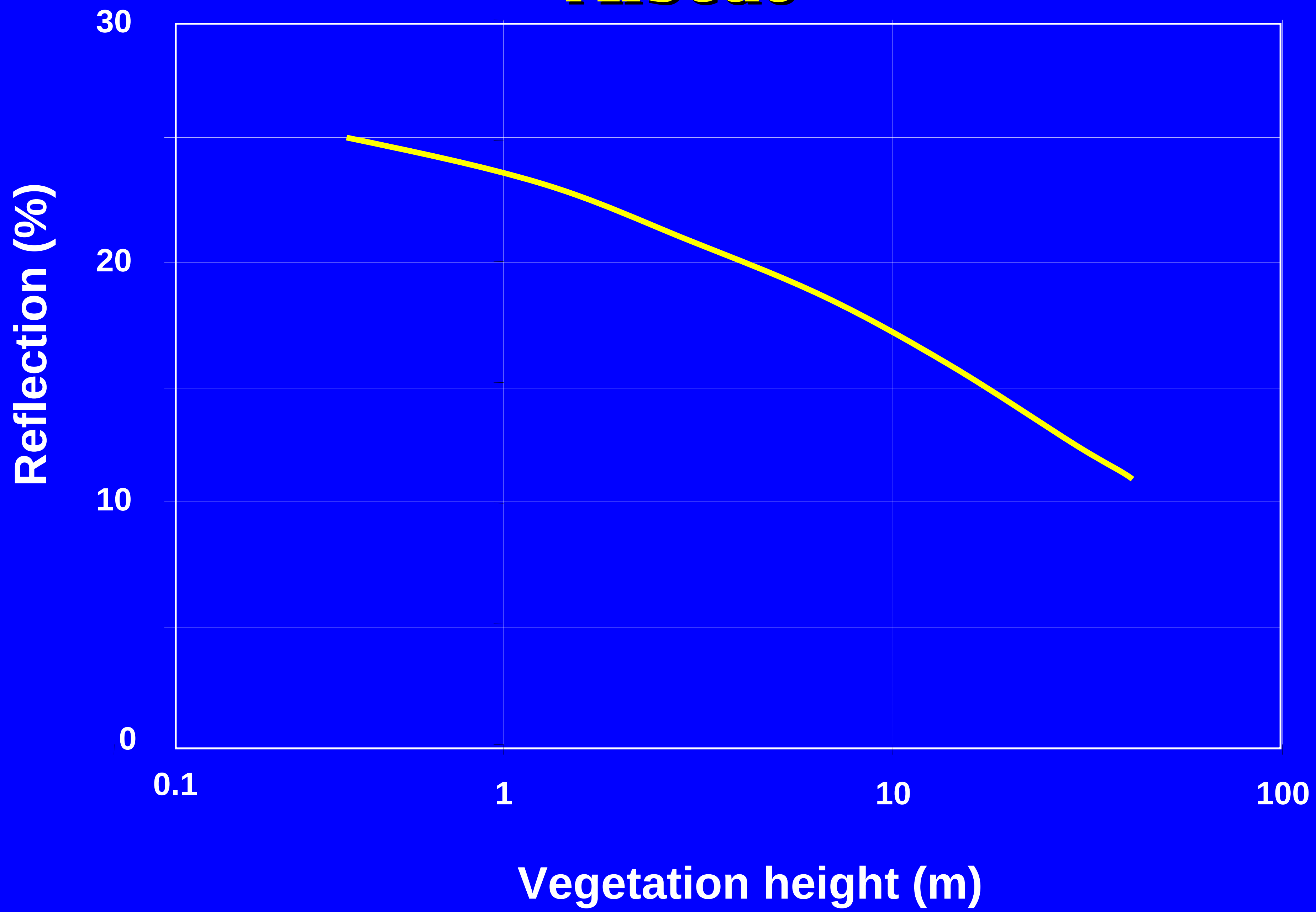


500	433	250	Q_s
535	468	285	$Q_s + q$

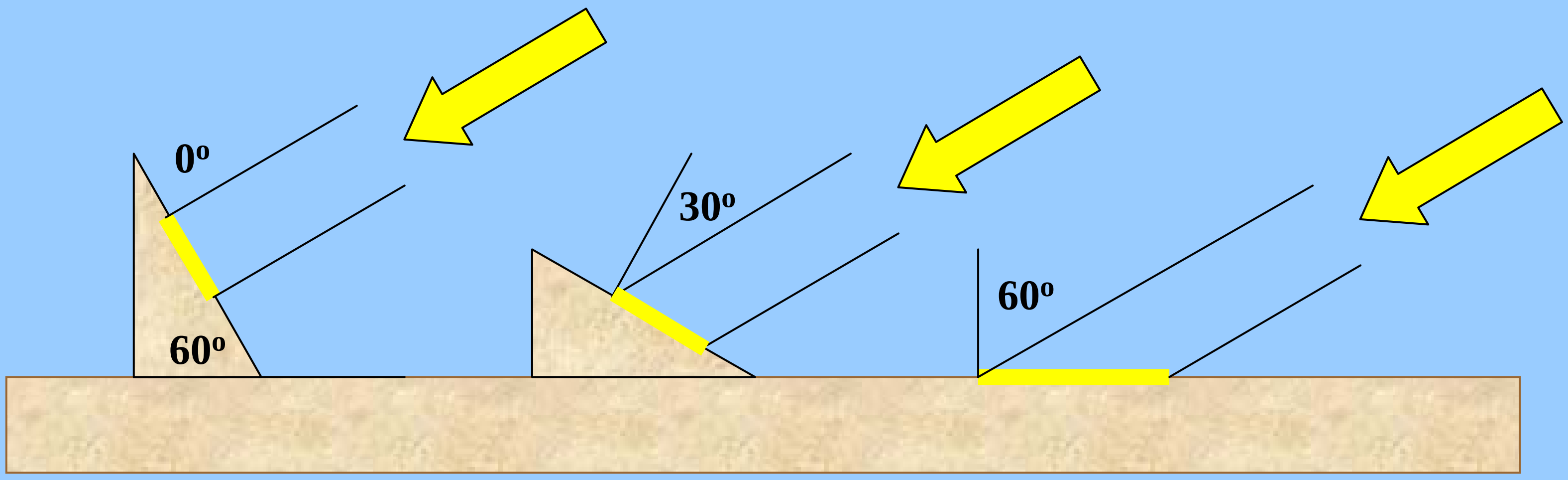
$R_s = Q_s + q$

$q \approx 0.15\ Q_s$ on a horizontal sfc

Albedo



Net solar radiation (W m^{-2})

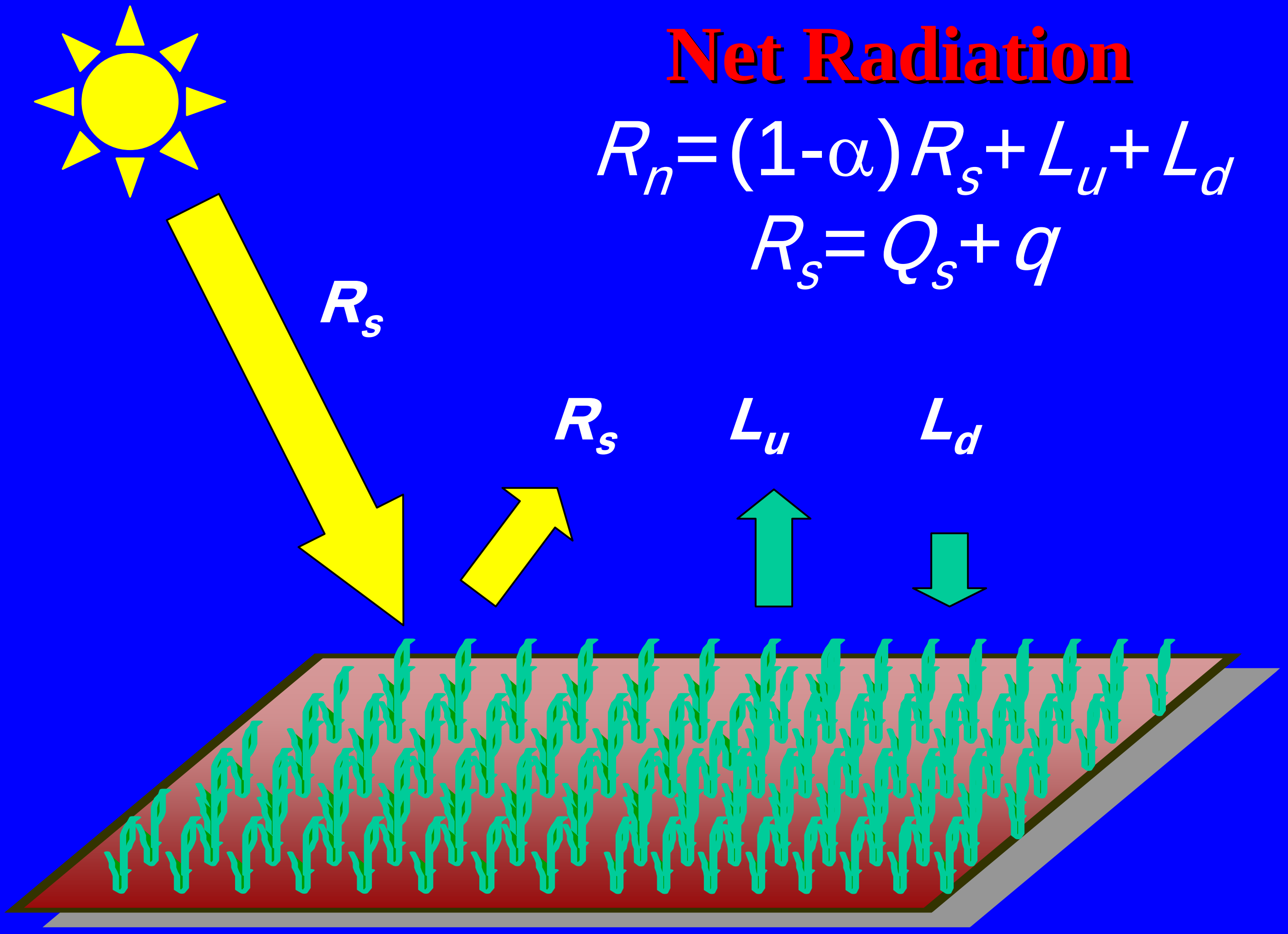


500	433	250	Q_s
535	468	285	$Q_s + q$
401	351	214	$\alpha = 0.25$

Net Radiation

$$R_n = (1-\alpha)R_s + L_u + L_d$$

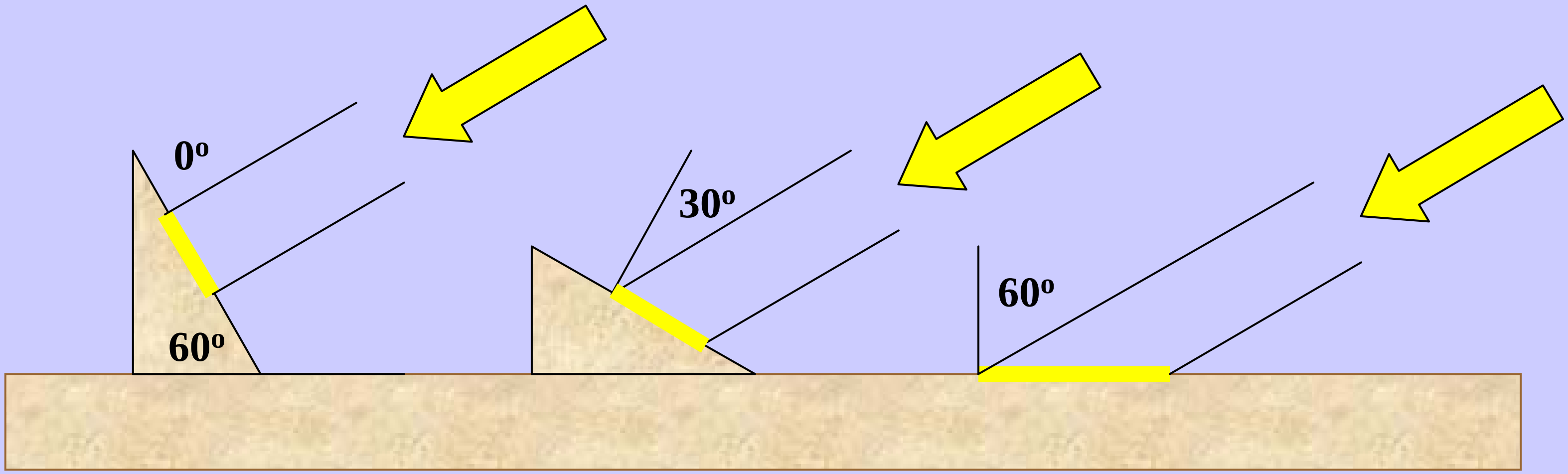
$$R_s = Q_s + q$$



cloudy *clear*

$L_u + L_d$ = -10 W m^{-2} to $L_u + L_d$ = -100 W m^{-2}

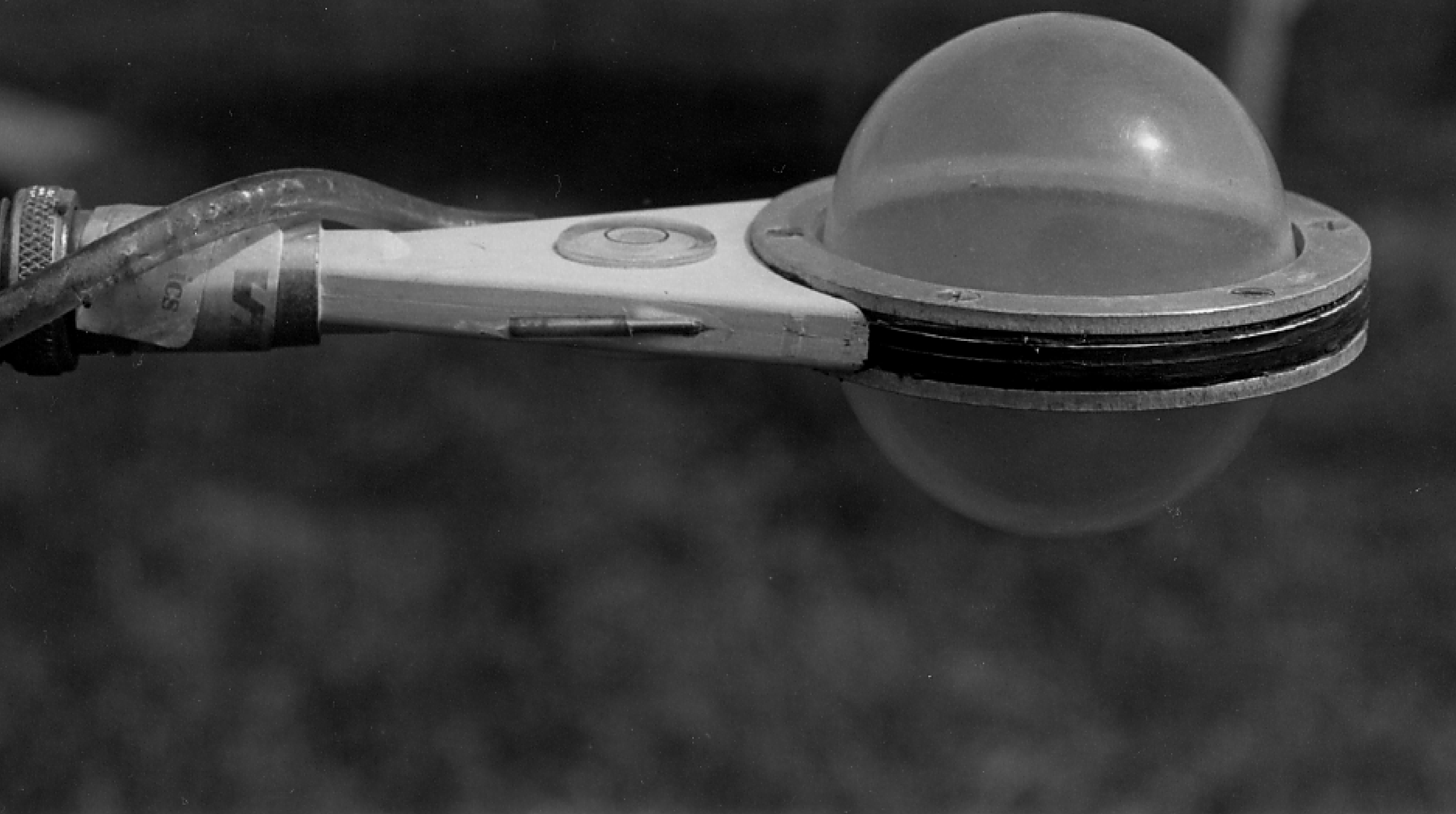
Net radiation (W m^{-2})



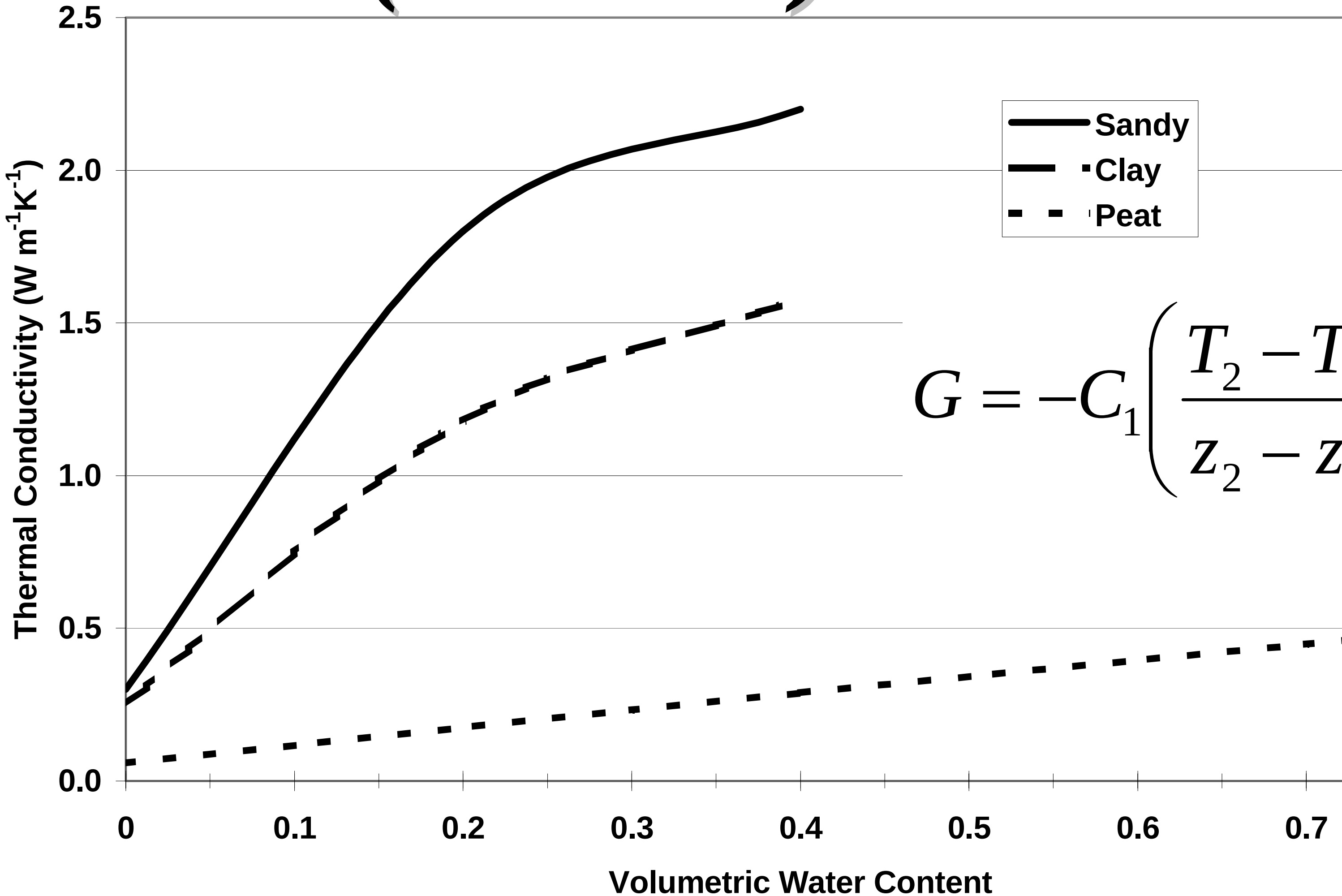
500	433	250	Q_s
535	468	285	$Q_s + q$
401	351	214	$\alpha = 0.25$
301	251	114	$R_{Ln} = -100$

$$R_n = R_{sd}\left(1-\alpha\right) + R_{Ld} + R_{Lu}$$

Net Radiometer



Soil (Ground) Heat Flux

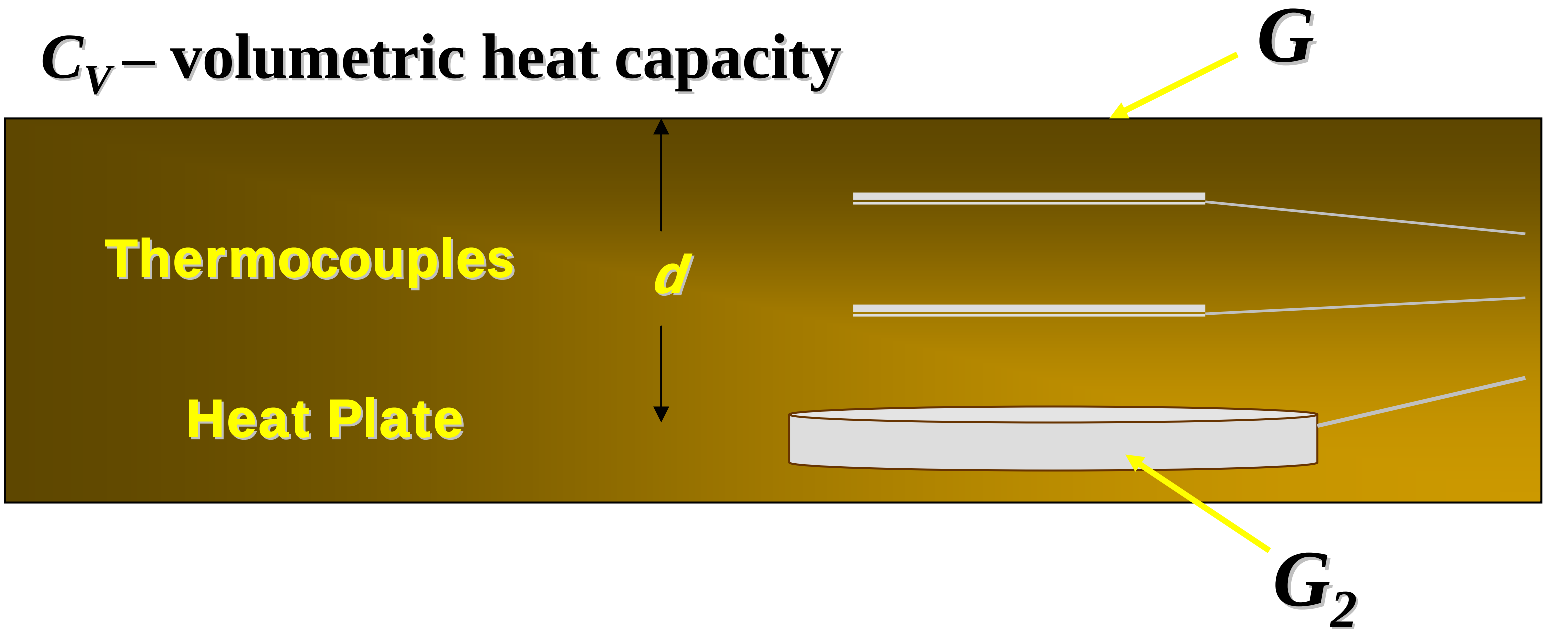


$$G = -C_1\left(\frac{T_2 - T_1}{z_2 - z_1}\right)$$

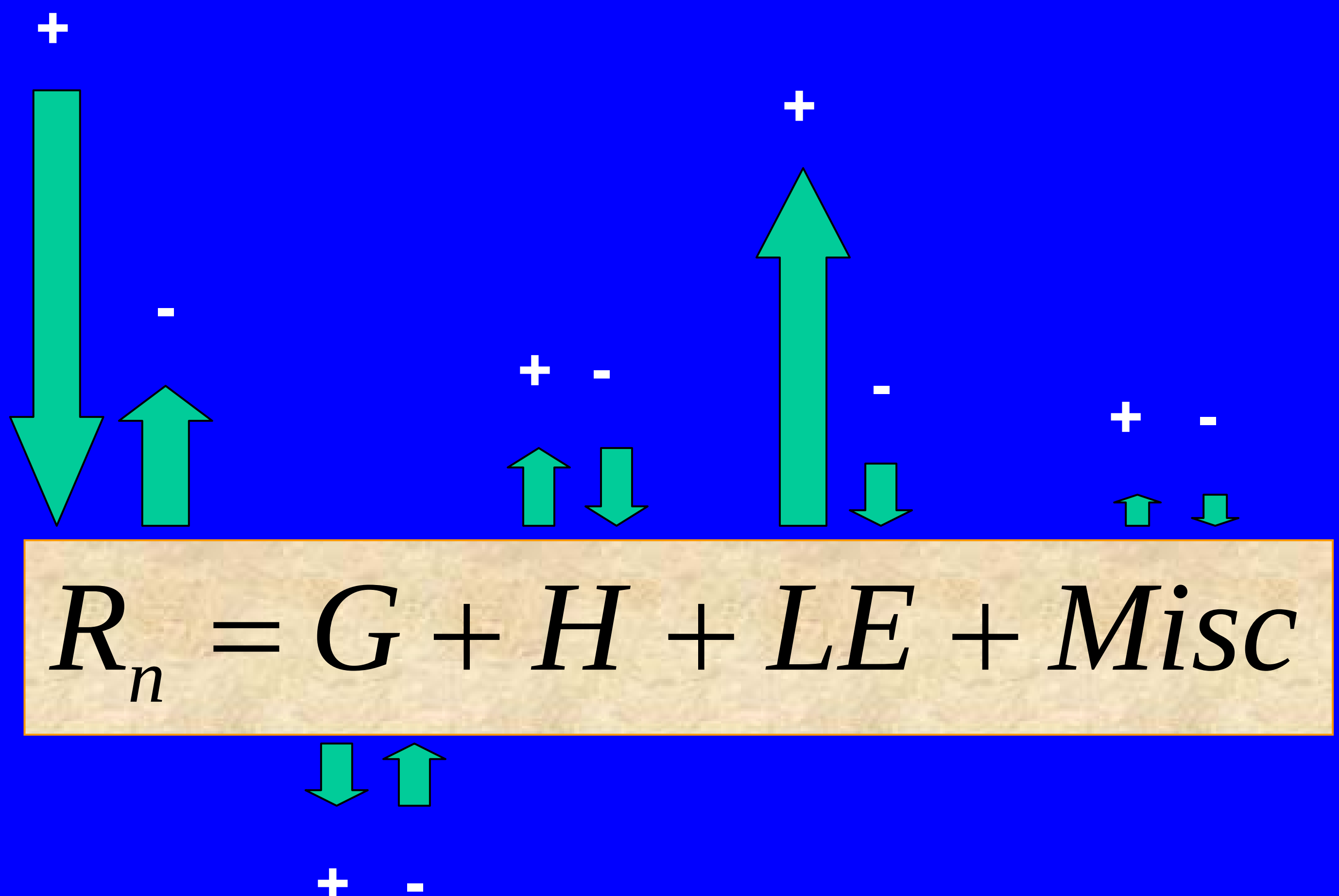
Soil Heat Flux Density (*G*)

$$G = G_2 + C_V \left(\frac{T_f - T_i}{t_f - t_i} \right) d$$

C_V – volumetric heat capacity



SURFACE ENERGY BUDGETS



$$R_n = G + H + LE + Misc$$

Sensible Heat Flux Density

$$H = -\rho C_p \kappa \left(\frac{T_2 - T_1}{z_2 - z_1} \right)$$

$$H = -\rho C_p \left(\frac{T_2 - T_1}{r_h} \right)$$

$$\frac{1}{r_h} = \frac{\kappa}{z_2 - z_1} = g_h$$

Latent Heat Flux Density

$$LE = -\kappa\left(\frac{\rho C_p}{\gamma}\right)\left(\frac{e_2 - e_1}{z_2 - z_1}\right)$$

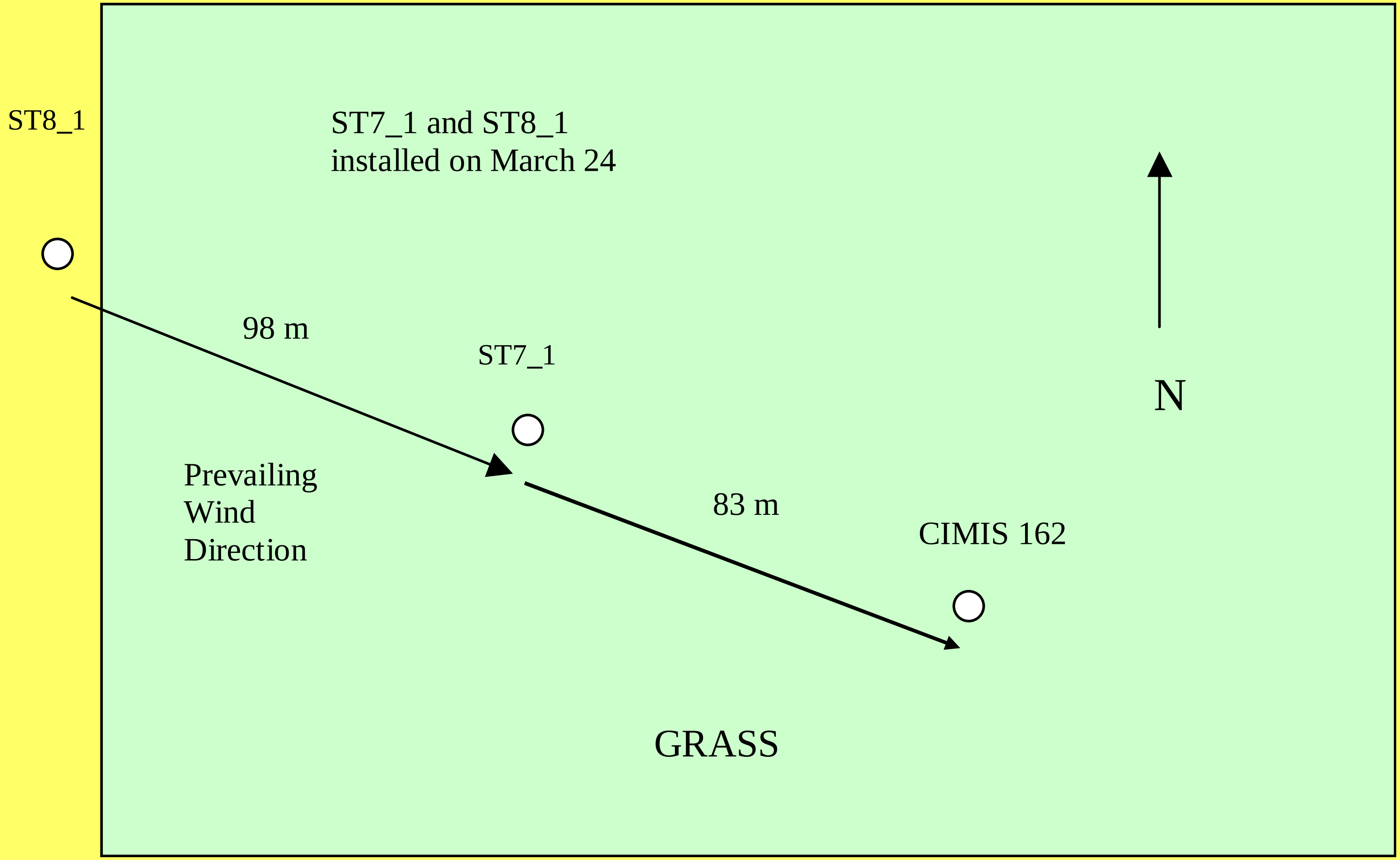
$$LE = -\left(\frac{\rho C_p}{\gamma}\right)\left(\frac{e_2 - e_1}{r_w}\right)$$

$$\frac{1}{r_w} = \frac{\kappa}{z_2 - z_1} = g_w$$

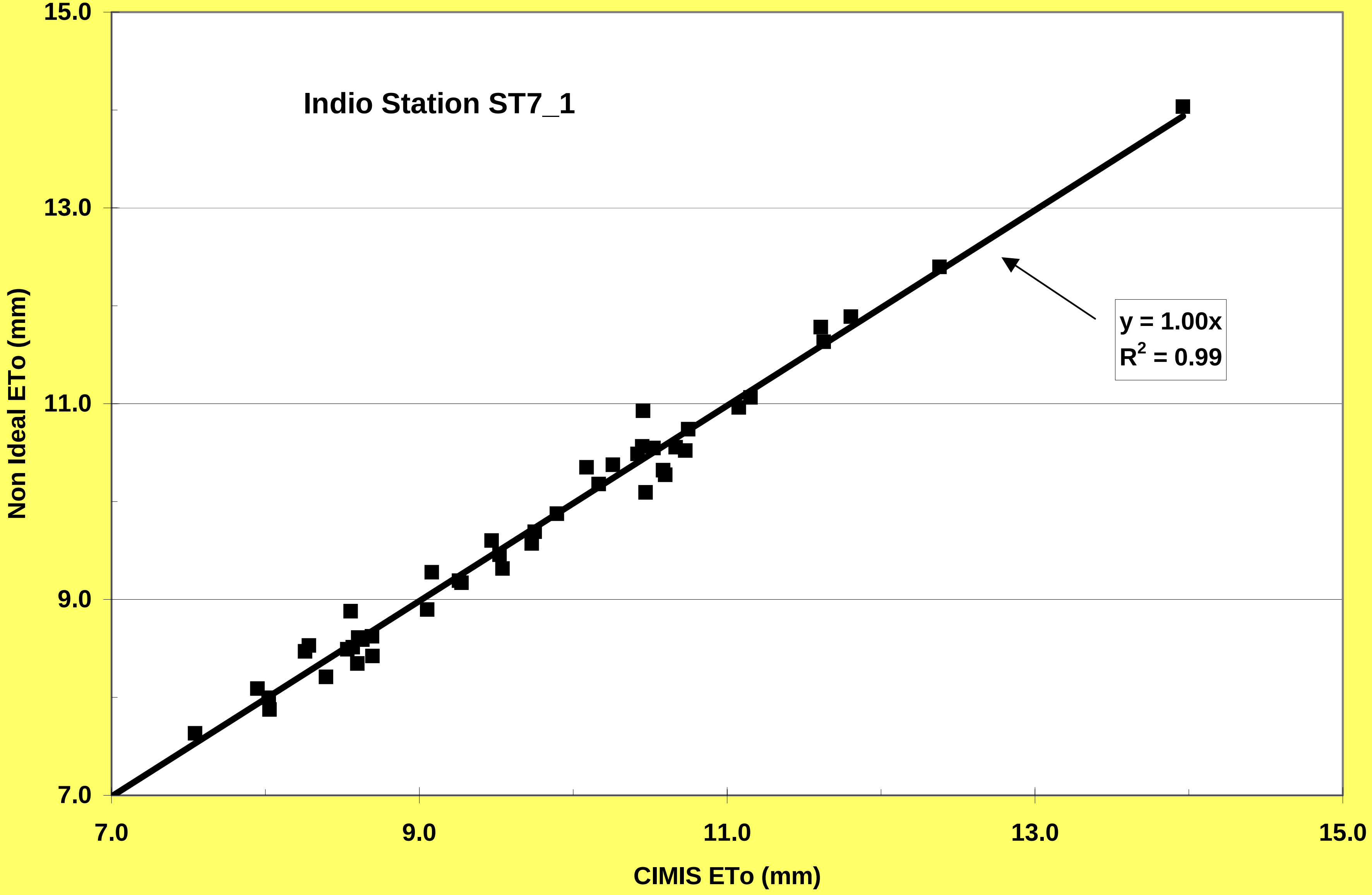
Microclimate & ETo

- Fetch Requirements
- Shading
- Wind blocking
- Marine effects

Fetch Requirements (Indio)



Fetch (98 m Vs 181 m)



Empirical ETo – El Dorado Country Club

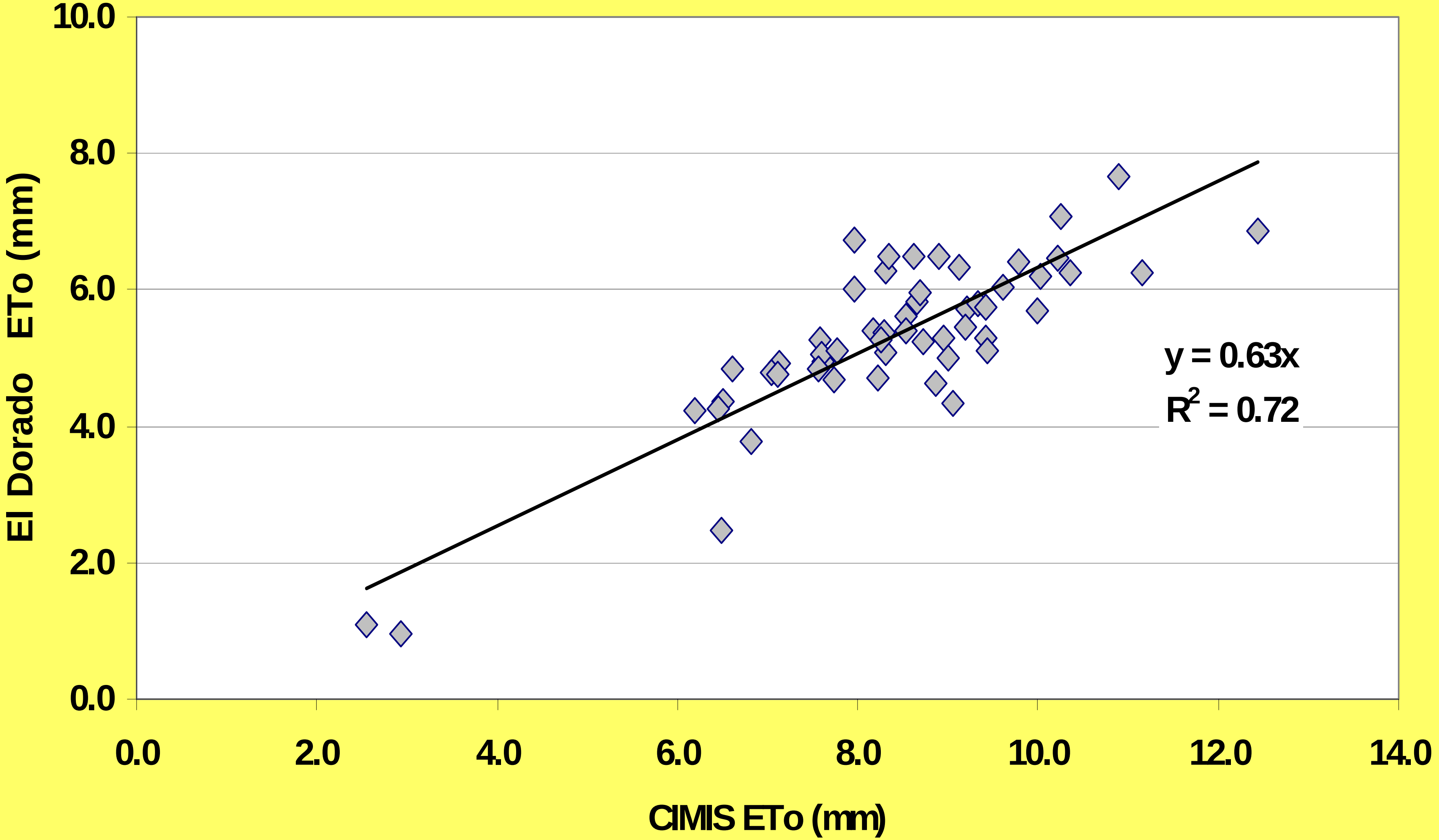
Adjustments for Regional effects

- Wind Blockage
- Sunrise-Sunset
- Advection

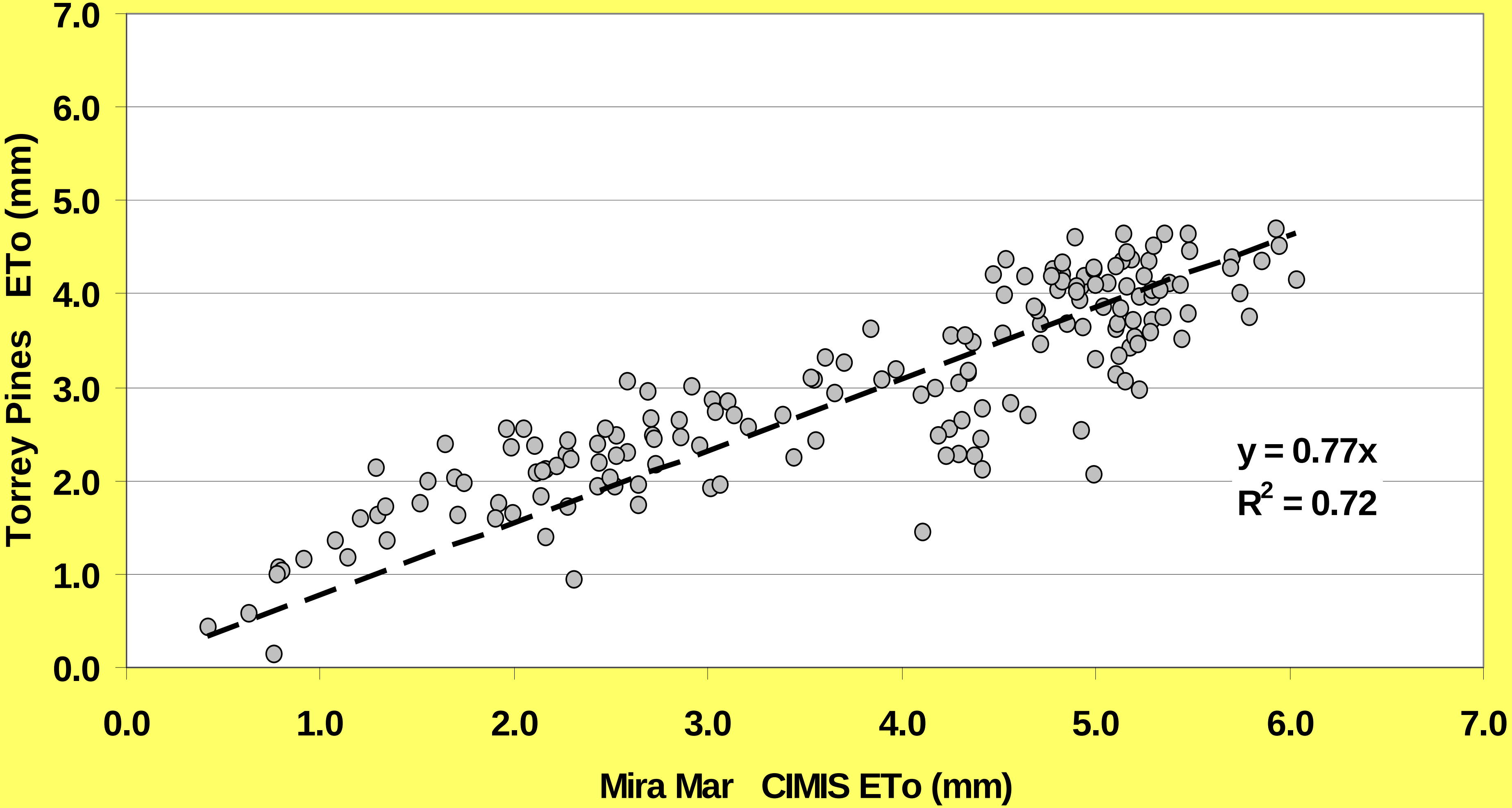
Empirical Equations

- CIMIS
- Regional effects

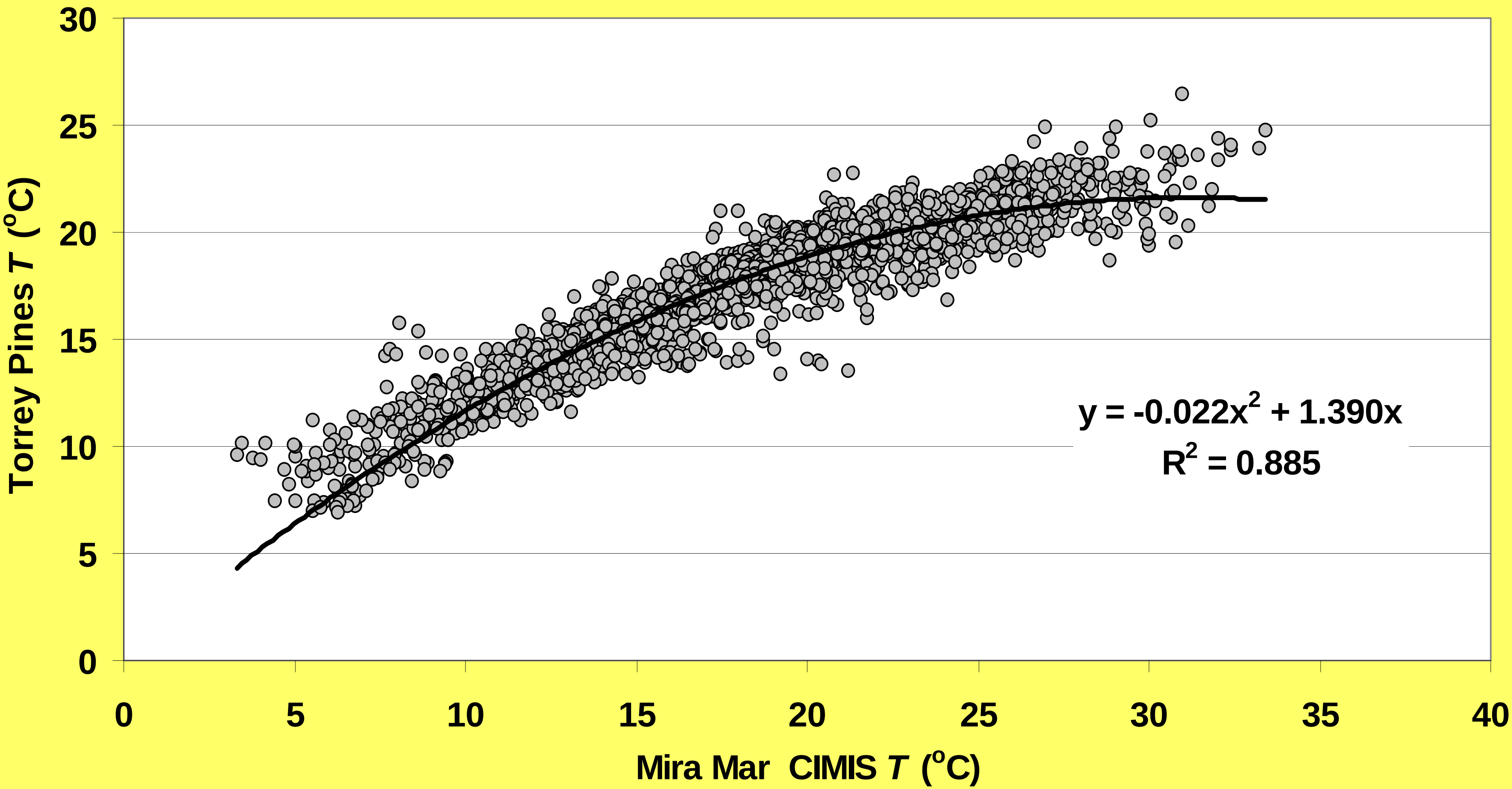
El Dorado Country Club



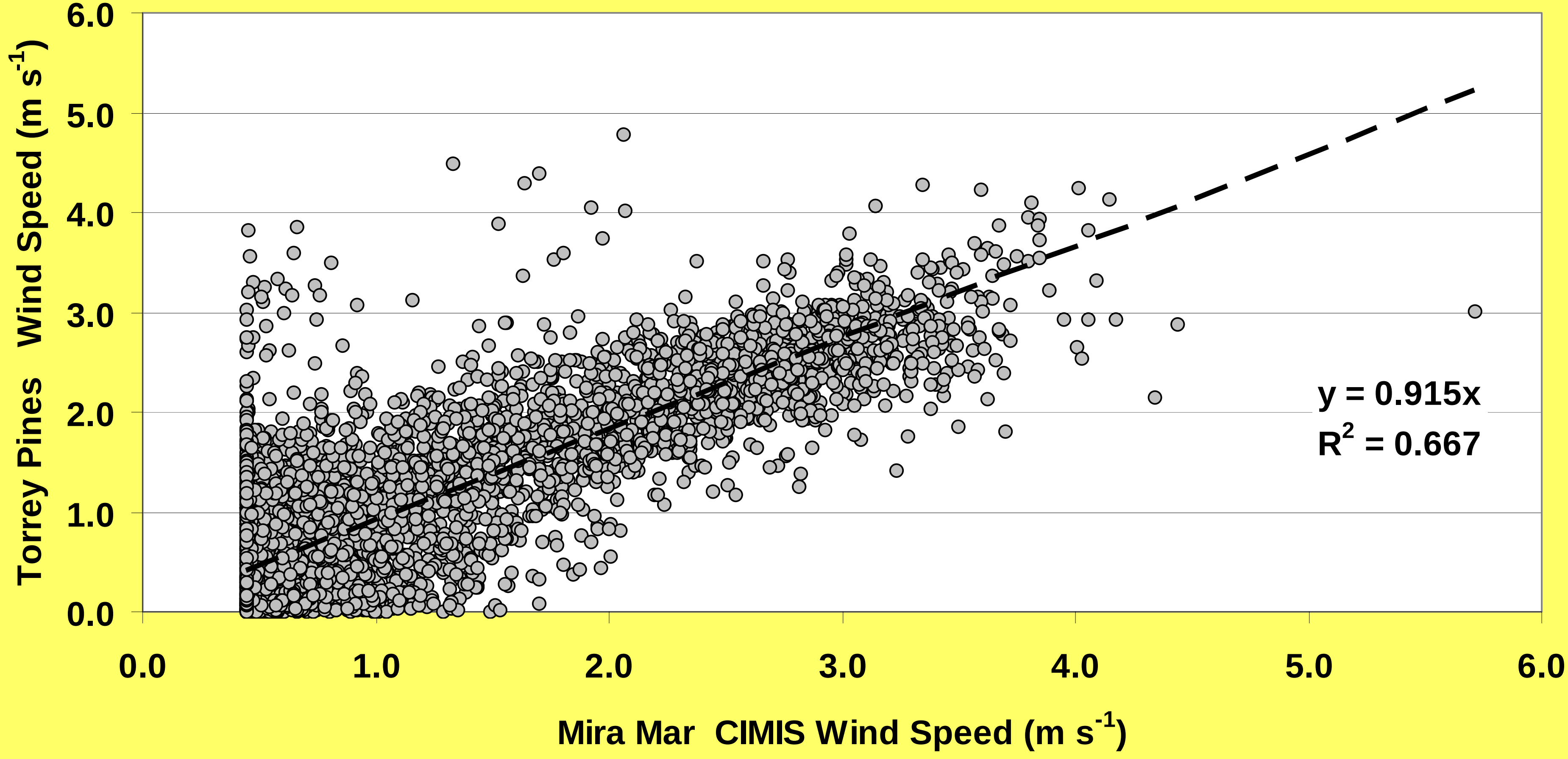
Torrey Pines Vs Mira Mar



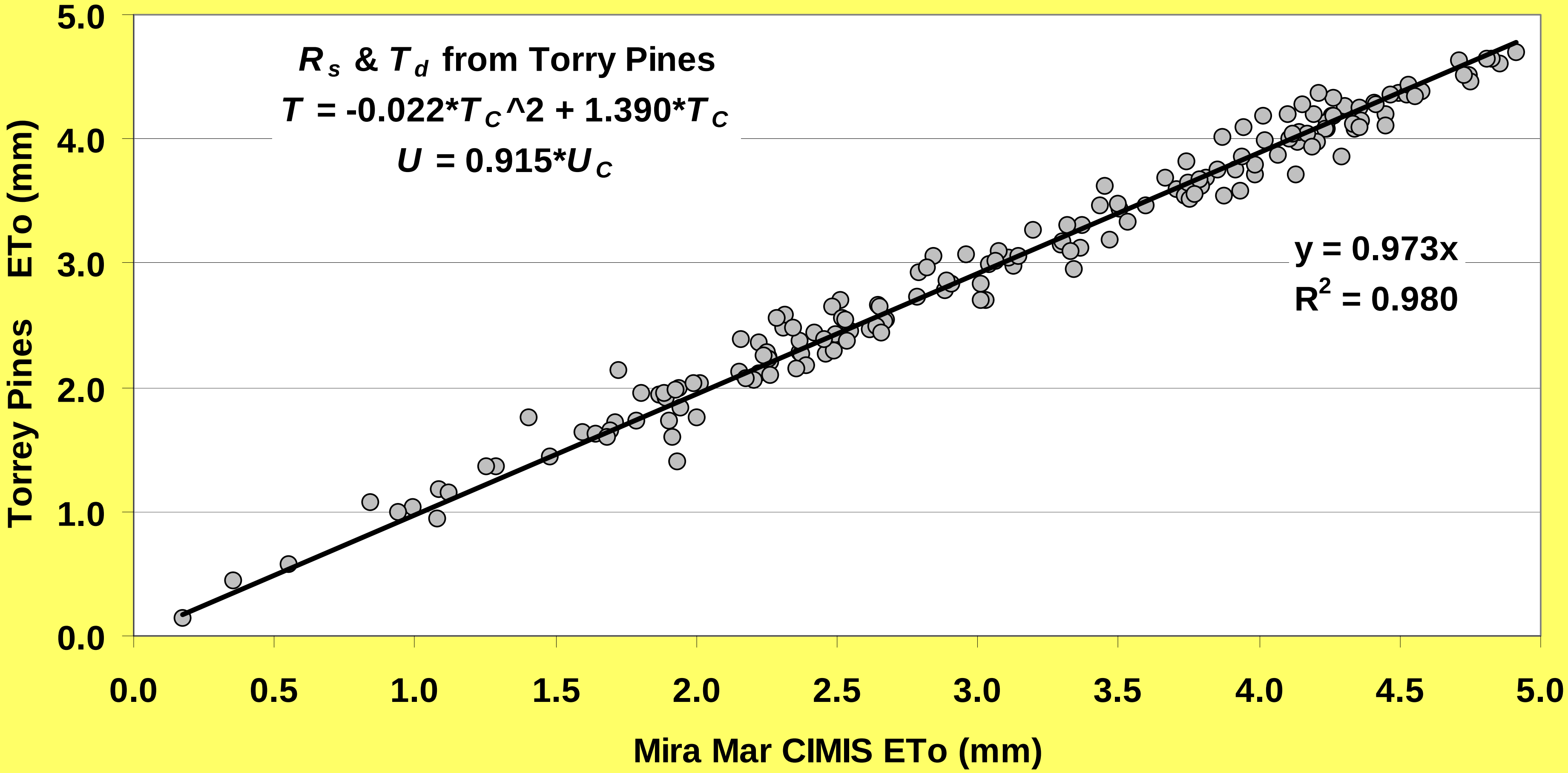
Temperature Model



Wind Correction



Torrey Pines ETo Model

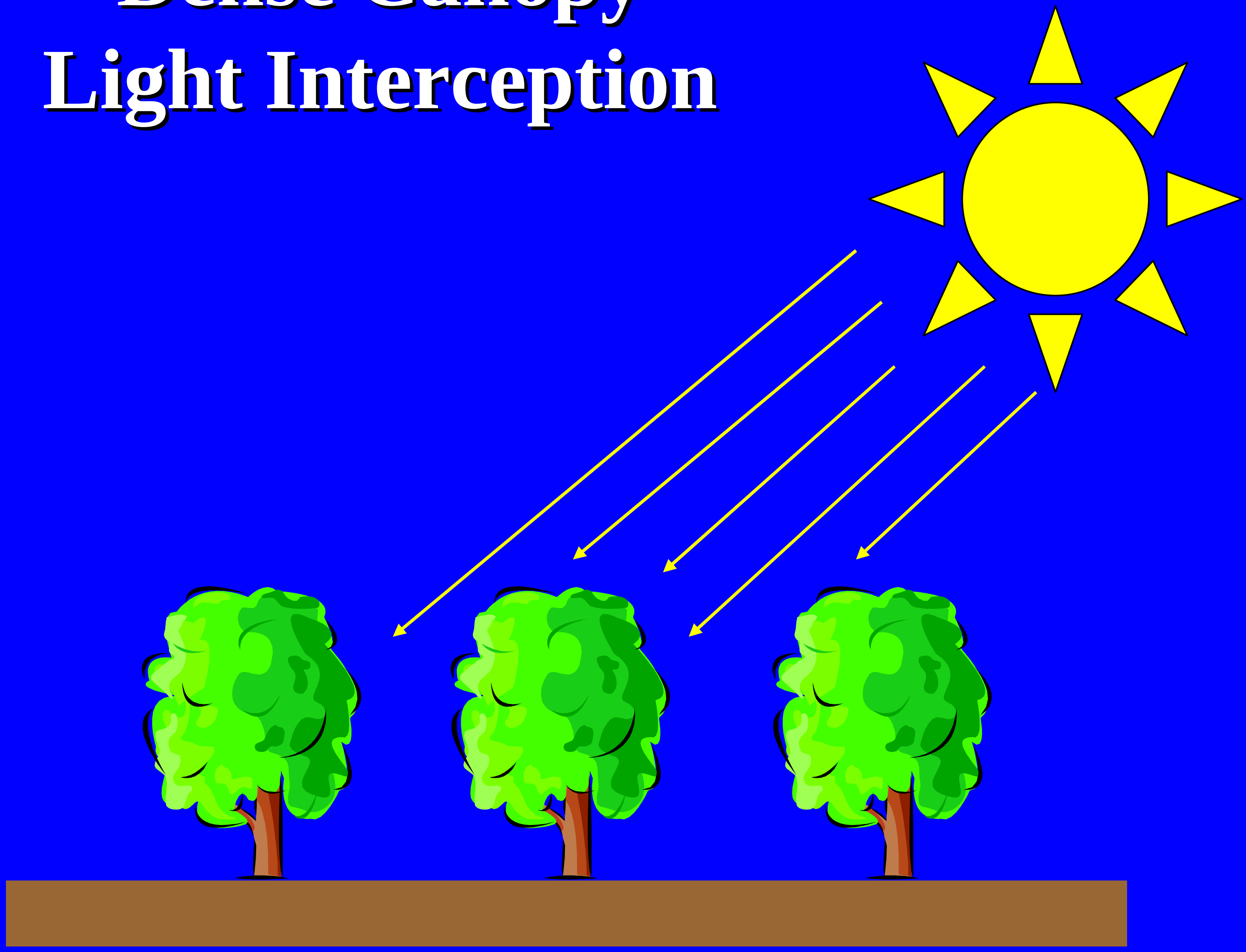


Landscape Coefficient

$$K_L = \frac{ET_L}{ET_o}$$

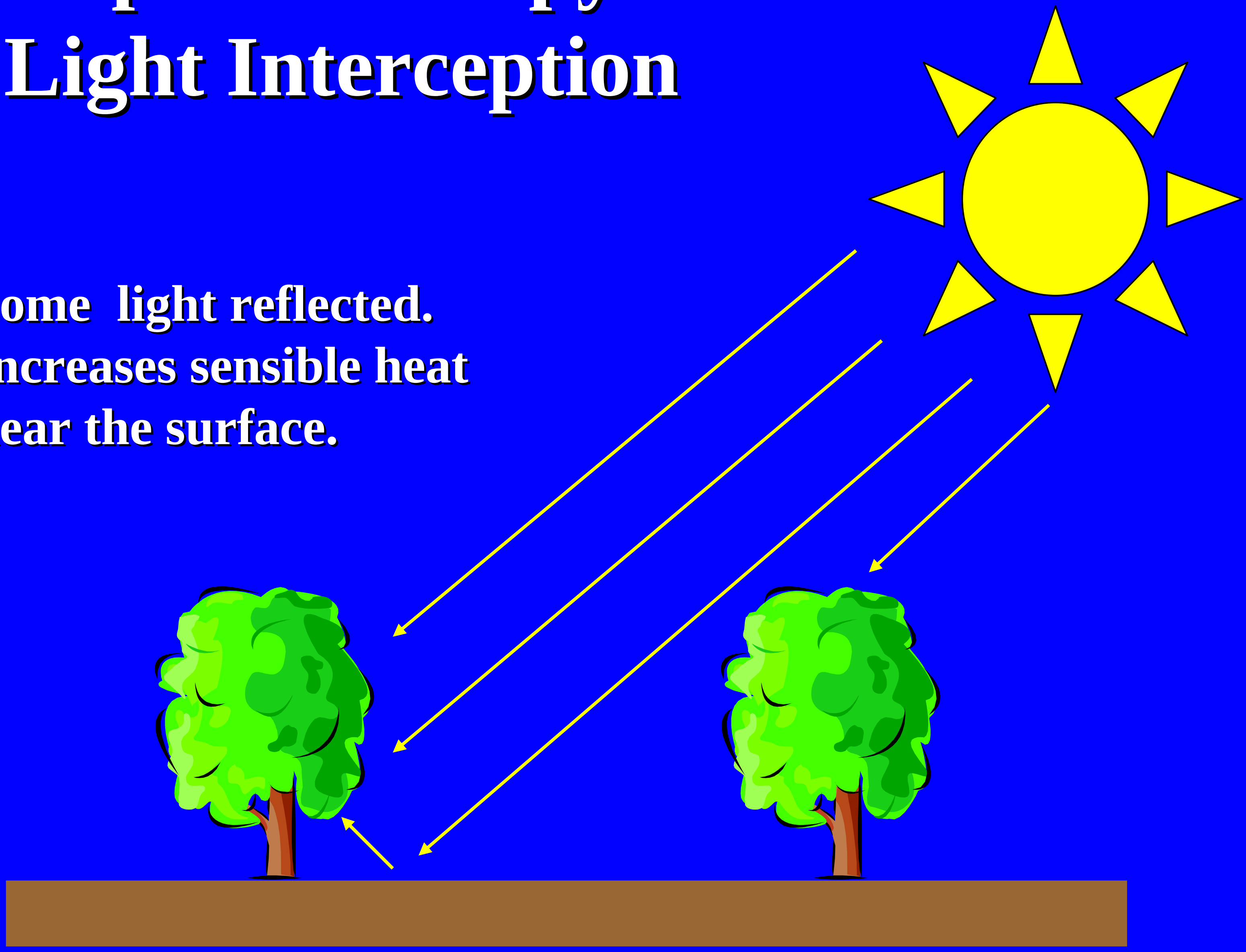
ET_L - measured ET_o - estimated

Dense Canopy
Light Interception

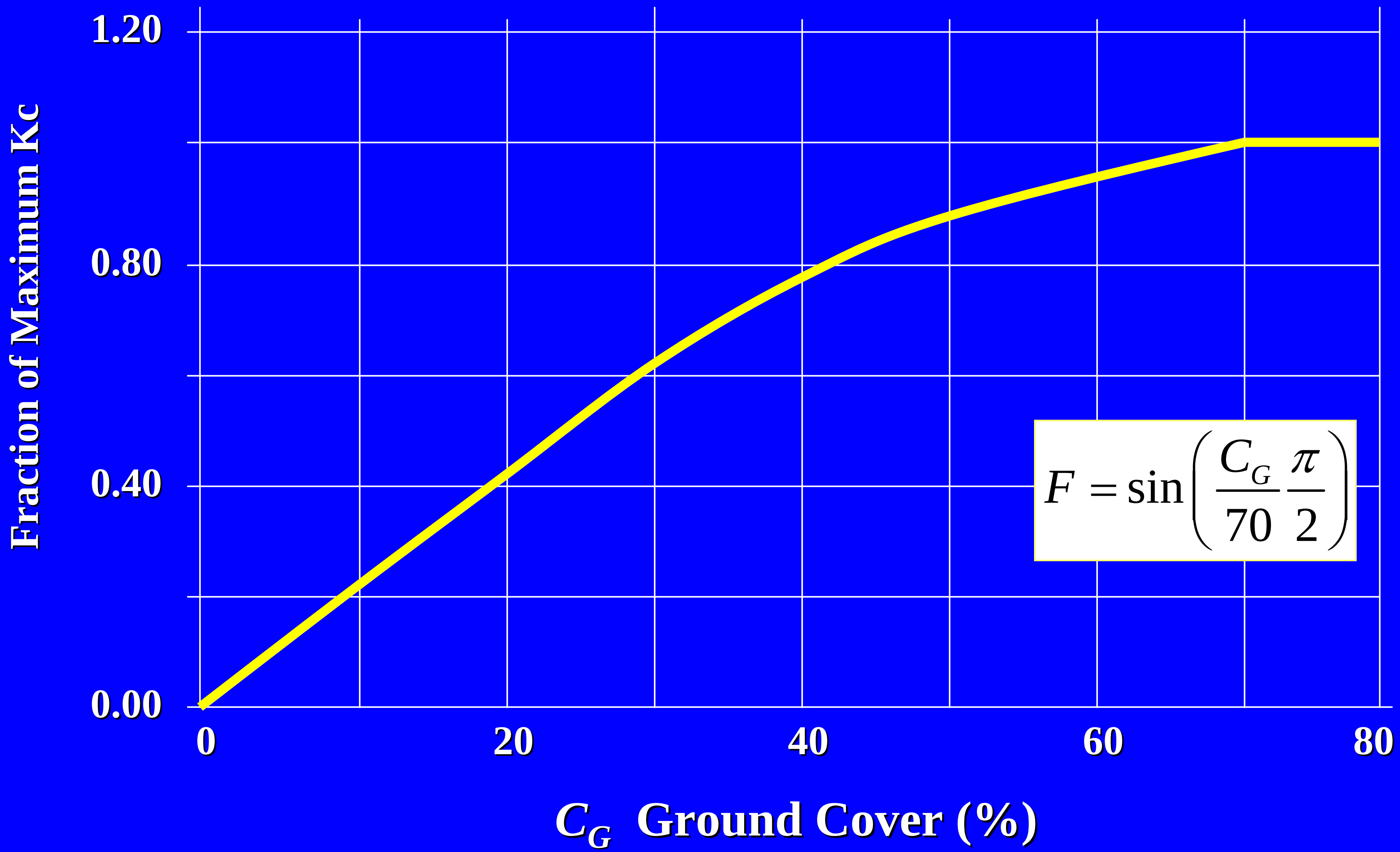


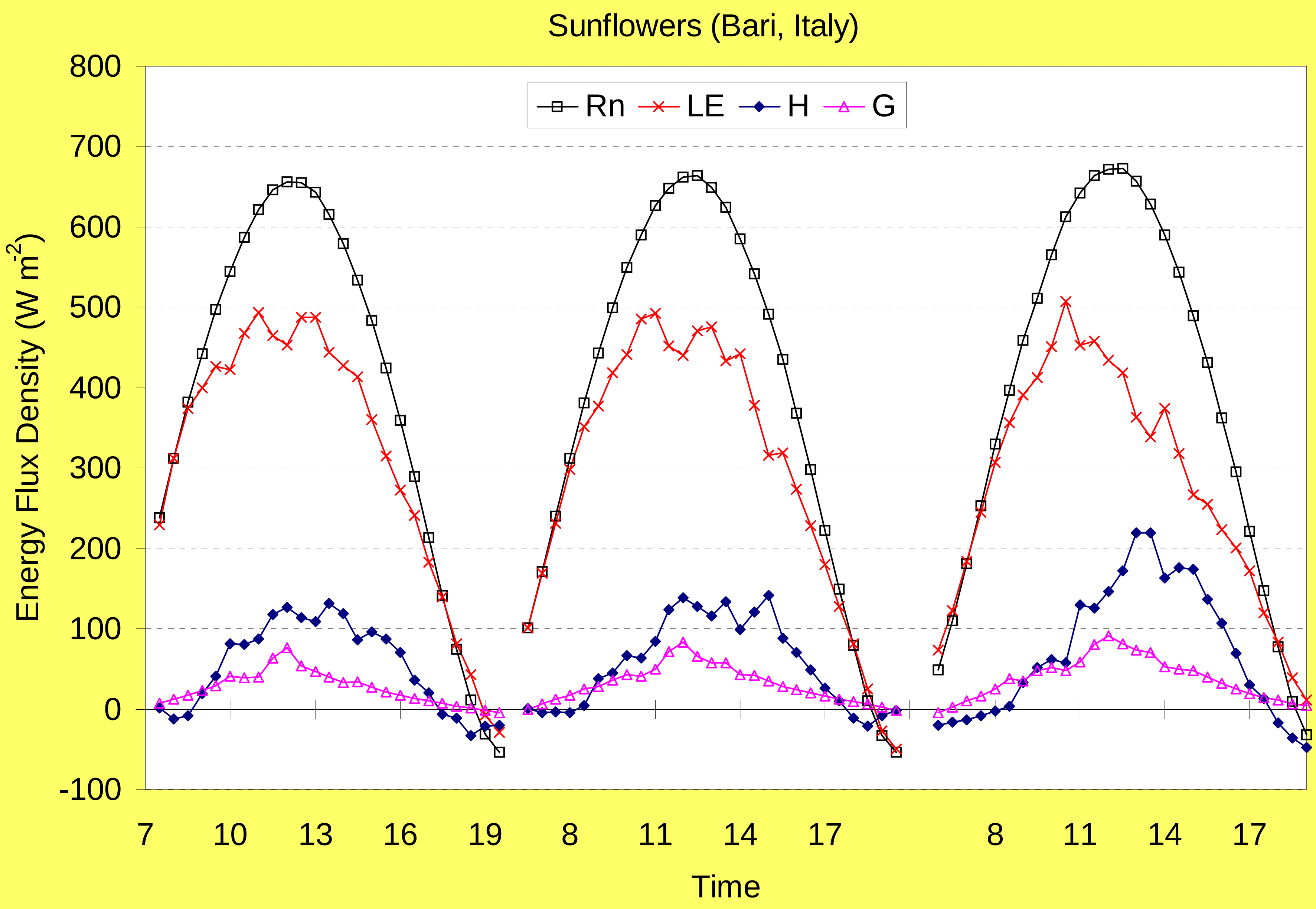
Sparse Canopy
Light Interception

Some light reflected.
Increases sensible heat
near the surface.



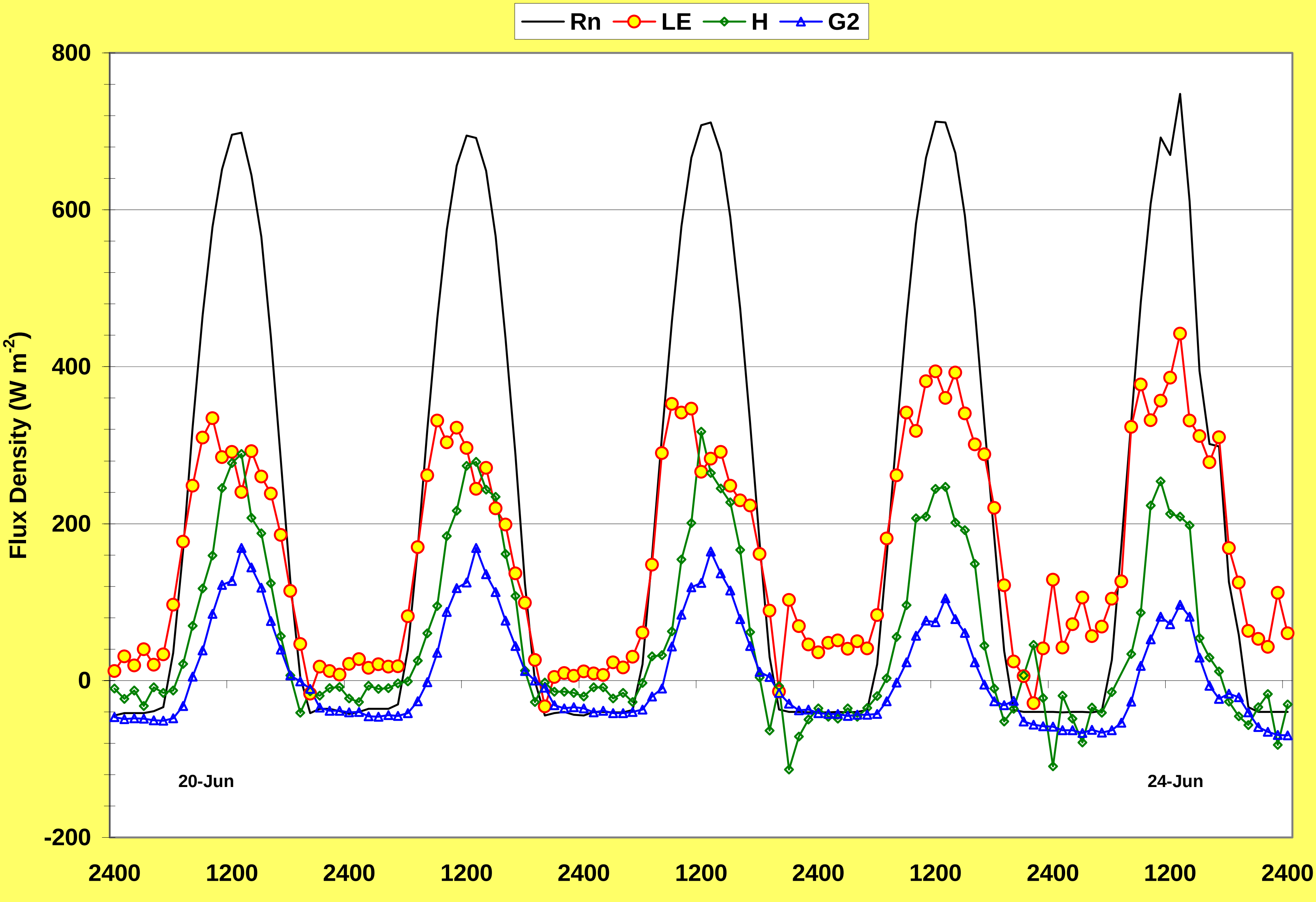
Density Correction



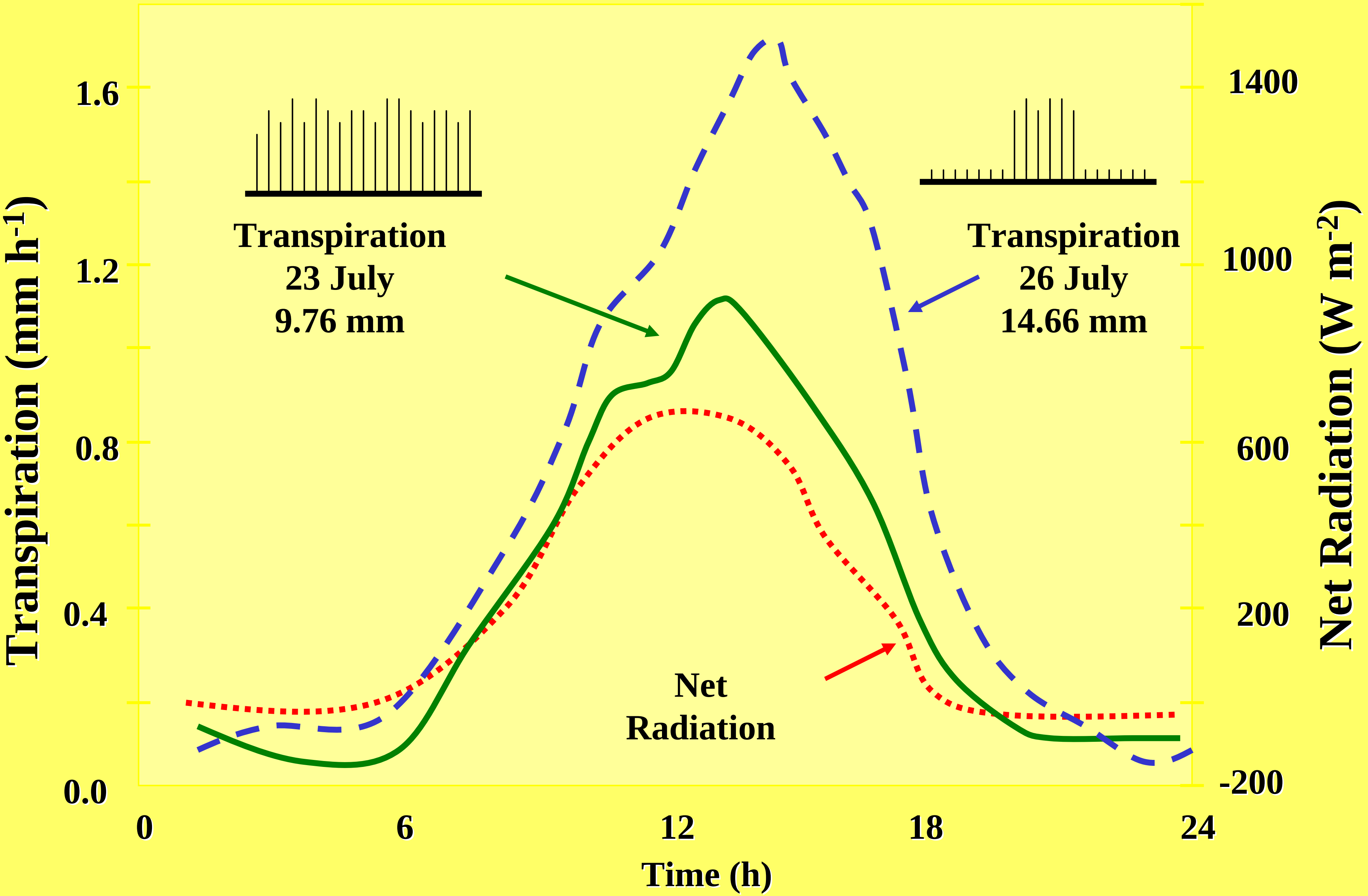


Sunflowers (Bari, Italy)
Rn
LE
H
G
Energy Flux Density (W m-2)
800
700
600
500
400
300
200
100
0
-100
7
10
13
16
19
8
11
14
17
8
11
14
17
Time

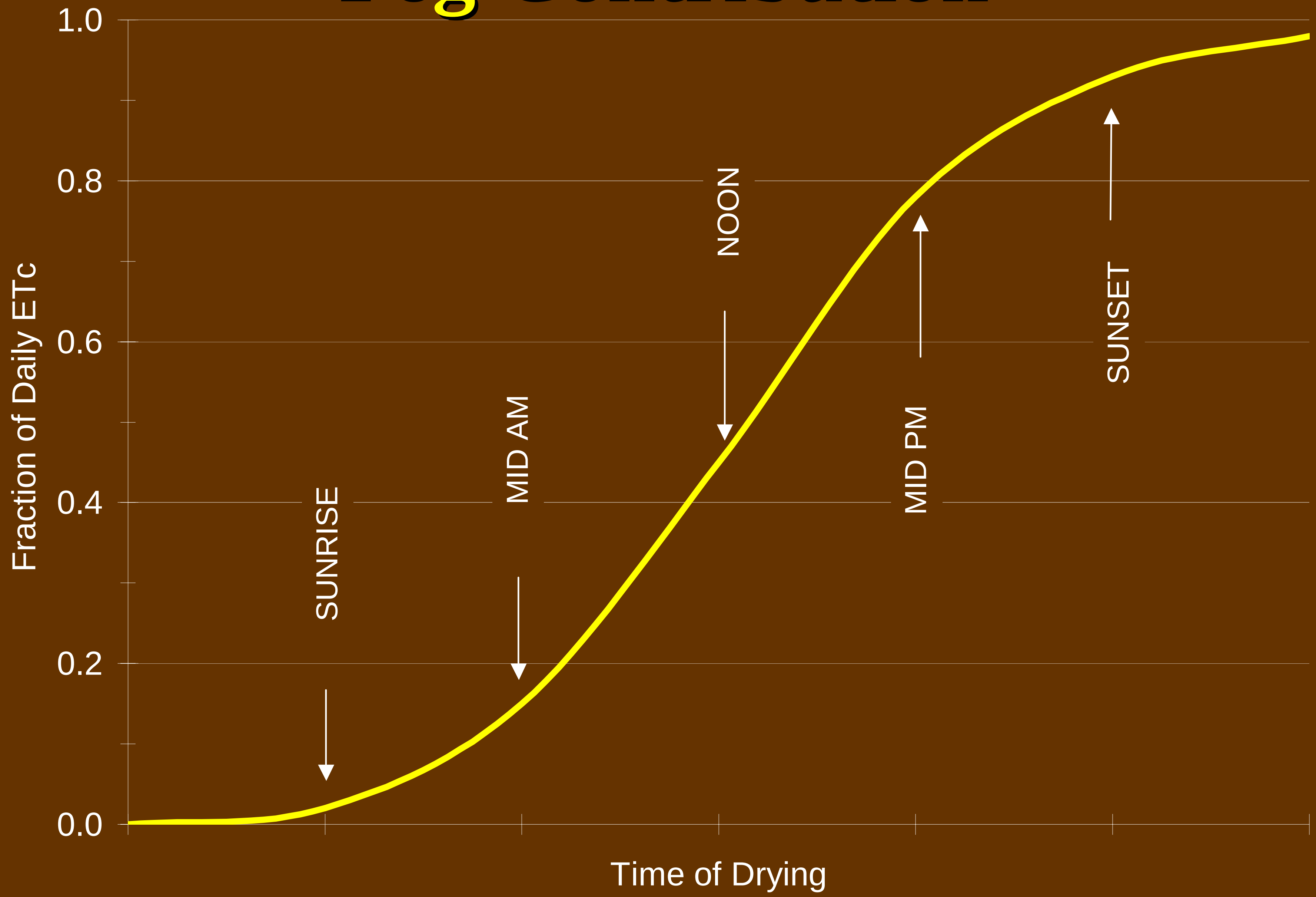
Citrus Energy Balance - Lindsay 2001



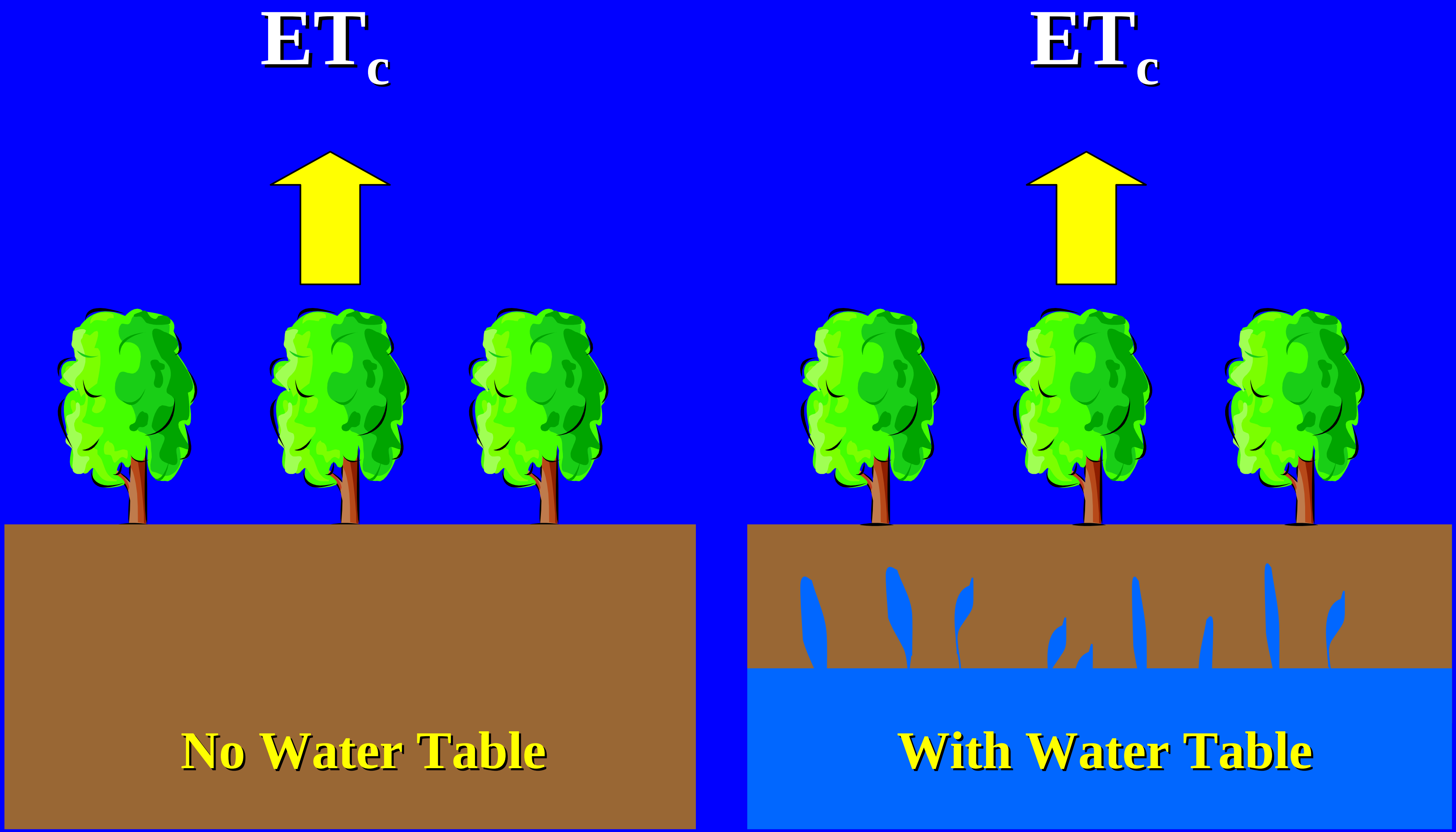
Local Advection



Fog Contribution



Water Table Contribution



The End

Thanks