Chapter 2: Heat and Water Vapor Transfer from Vegetation

Waring RH and SW Running. 1998. Forest Ecosystems, Analysis at Multiple Scales, 2nd ed. Academic Press, USA. Ch.2, Water cycle, 22-28.

Estimating environmental parameters

- Equations are based on the idea of energy balance
- Use values you can measure directly or estimate easily to estimate hard to determine processes
- Our goal is to figure out what happens to the water present in the system

A. Energy Balance

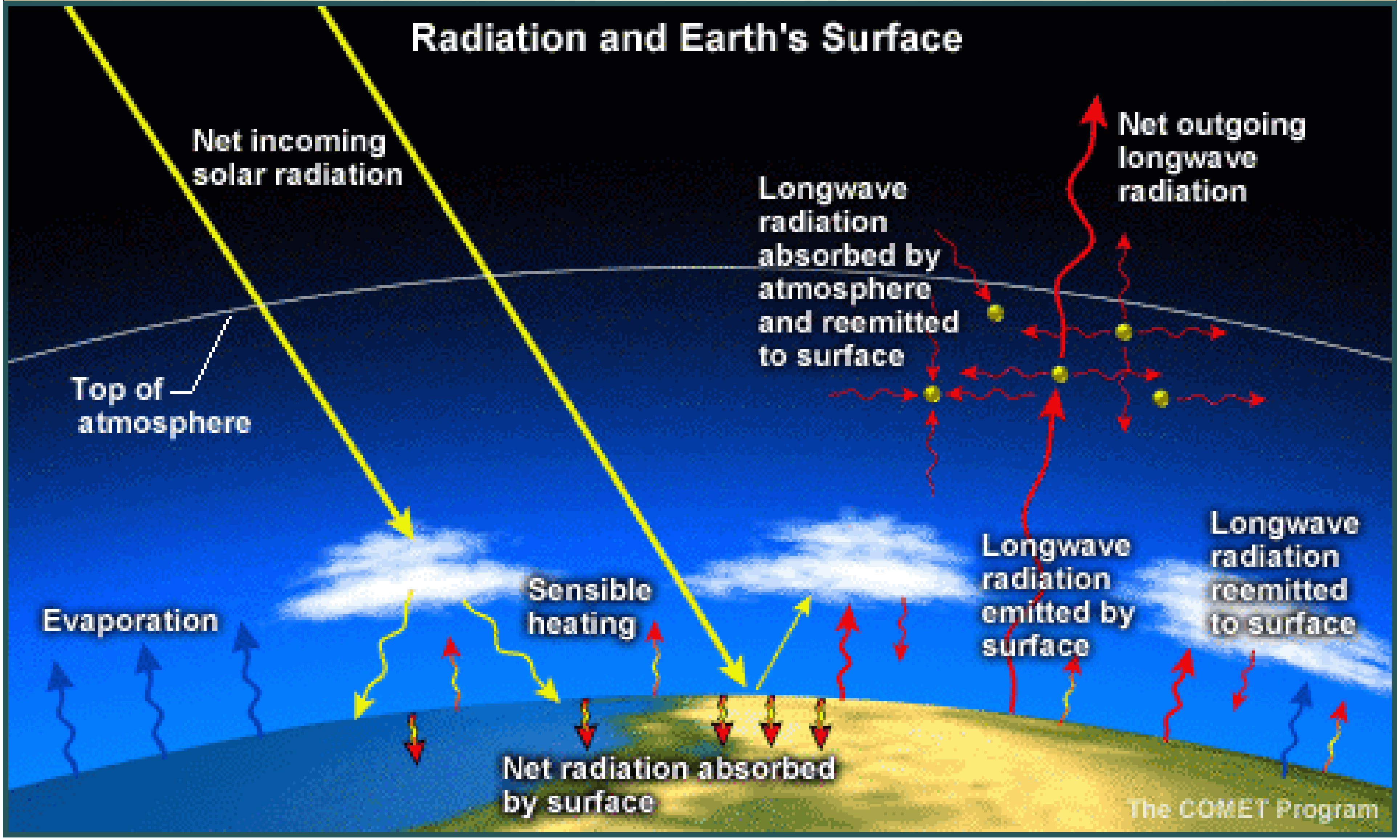
- Movement of water vapor is determined using:
  - Radiant energy in the system (Net Radiation)
  - Environmental variables controlling evaporation
    - Temperature of the environment compared to the surface
    - Humidity of the environment compared to the air very close to the surface
    - Movement of air

Net Radiation

- Net radiation is comprised of:
  - Short wave radiation – 95% of solar radiation is short wave
  - Long wave radiation
- Total radiation striking a surface comes from:
  - Direct short wave- sun
  - Diffuse short wave- sky
  - Reflected short wave- nearby surfaces
  - Long wave – atmospheric emission
  - Long wave – emission from nearby surfaces

$$R_n = (1 - \alpha)\, I_s + \varepsilon_L \sigma T^4 (\text{surface}) - \sigma T^4 (\text{sky}) \quad 2.1$$

Net Radiation = short wave radiation + long wave radiation

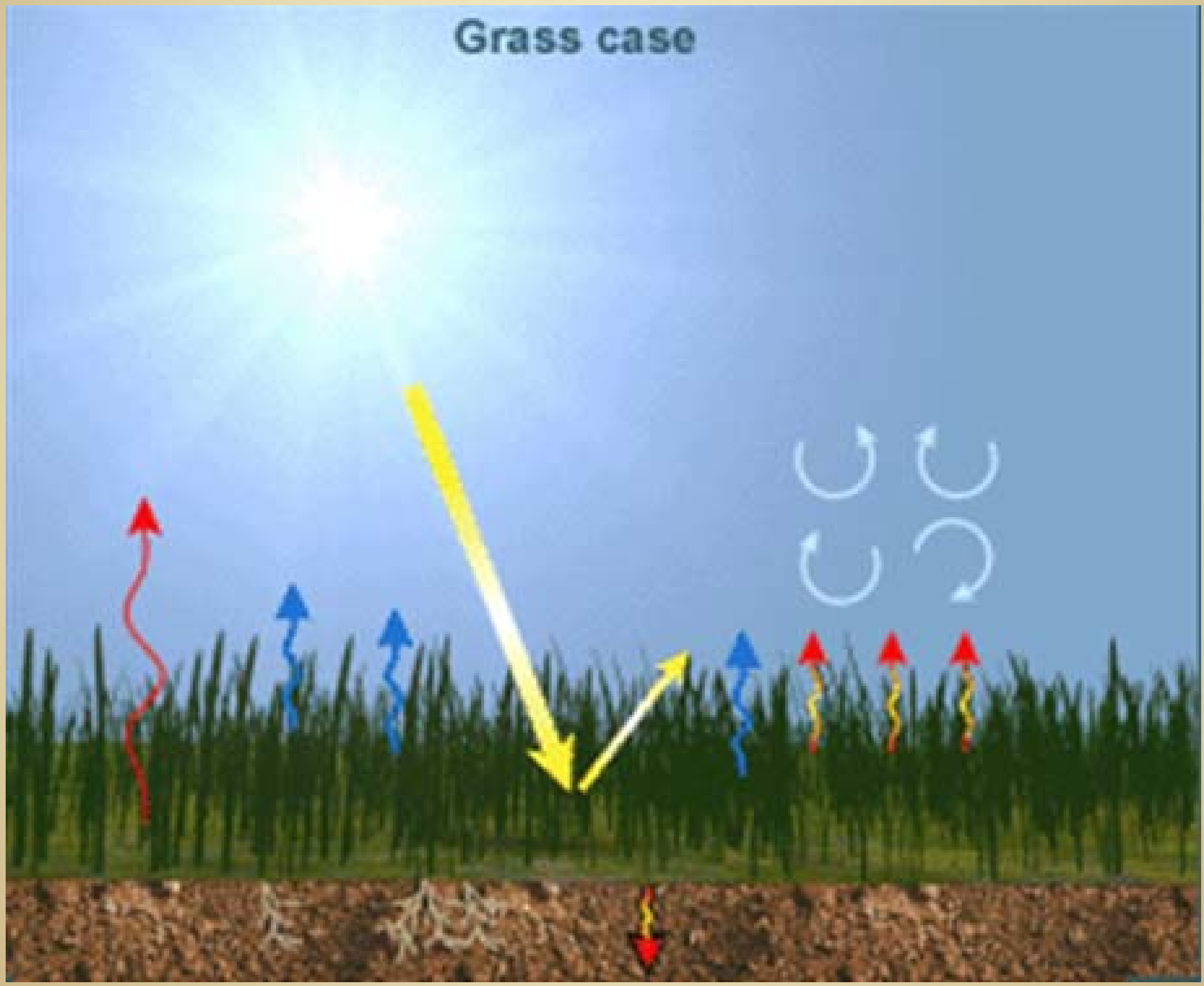


Surface Energy Balance

- Net radiant energy on a surface is comprised of:
  - Energy stored by the surface as heat (G)
    - Normally this is a small value on short timescales
  - Sensible heat flux (H) – Heat changing the air temperature
    - Value is hard to measure
  - Latent heat flux (λE) – Heat used to evaporate water

$$R_n - G = H + \lambda E \qquad 2.2$$

Net Radiation – Heat Storage = Sensible Heat Flux + Latent Heat Flux



Bowen Ratio (β)

- Relationship between sensible and latent heat losses. (H/ λE)
- Used to determine Latent Heat when Sensible Heat is unknown.
- Need to estimate Bowen ratio based on known information for this to work.

$$\lambda E = R_n / (1 + \beta) \quad 2.3$$

B. Evaporation from Wet Surfaces

- Movement of water vapor is determined using:
  - Radiant energy in the system (Net Radiation)
  - Environmental variables controlling evaporation
    - Temperature of the environment compared to the surface
    - Humidity of the environment compared to the air very close to the surface
    - Movement of air

Simple Evaporation Rate

$$E = (e_w - e_a)\, f(u) \qquad 2.4$$

Evaporation rate = evaporation from the surface * air circulation

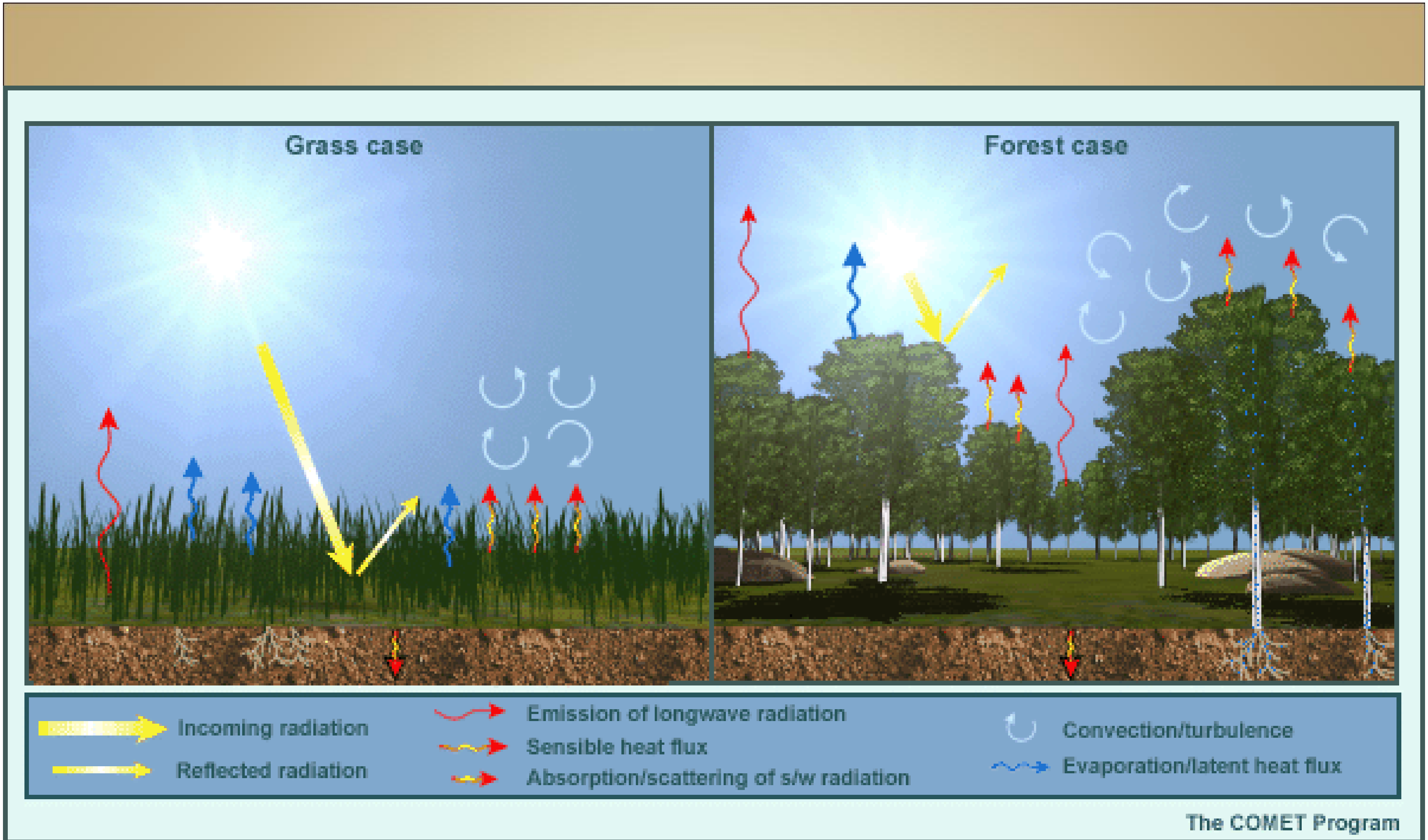
Evaporation from the surface $(e_w - e_a)$ is determined by the vapor pressure of the air at the surface compared to the surrounding air

$e_w > e_a$ Water evaporates from the surface into the air

$e_w = e_a$ Local equilibrium so no evaporation net change in water

$e_w < e_a$ Water condenses from the air to the surface

Increasing turbulence will increase Evaporation.


Grass case
Forest case
Incoming radiation
Reflected radiation
Emission of longwave radiation
Sensible heat flux
Absorption/scattering of s/w radiation
Convection/turbulence
Evaporation/latent heat flux
The COMET Program

Finding Evaporation without Surface Temperature

- Using the Penman equation:

$$E = E_{eq} + D\, g_b / \zeta \qquad 2.5$$

In this equation

- E_{eq} is the evaporation from a specific surface at equillibrium

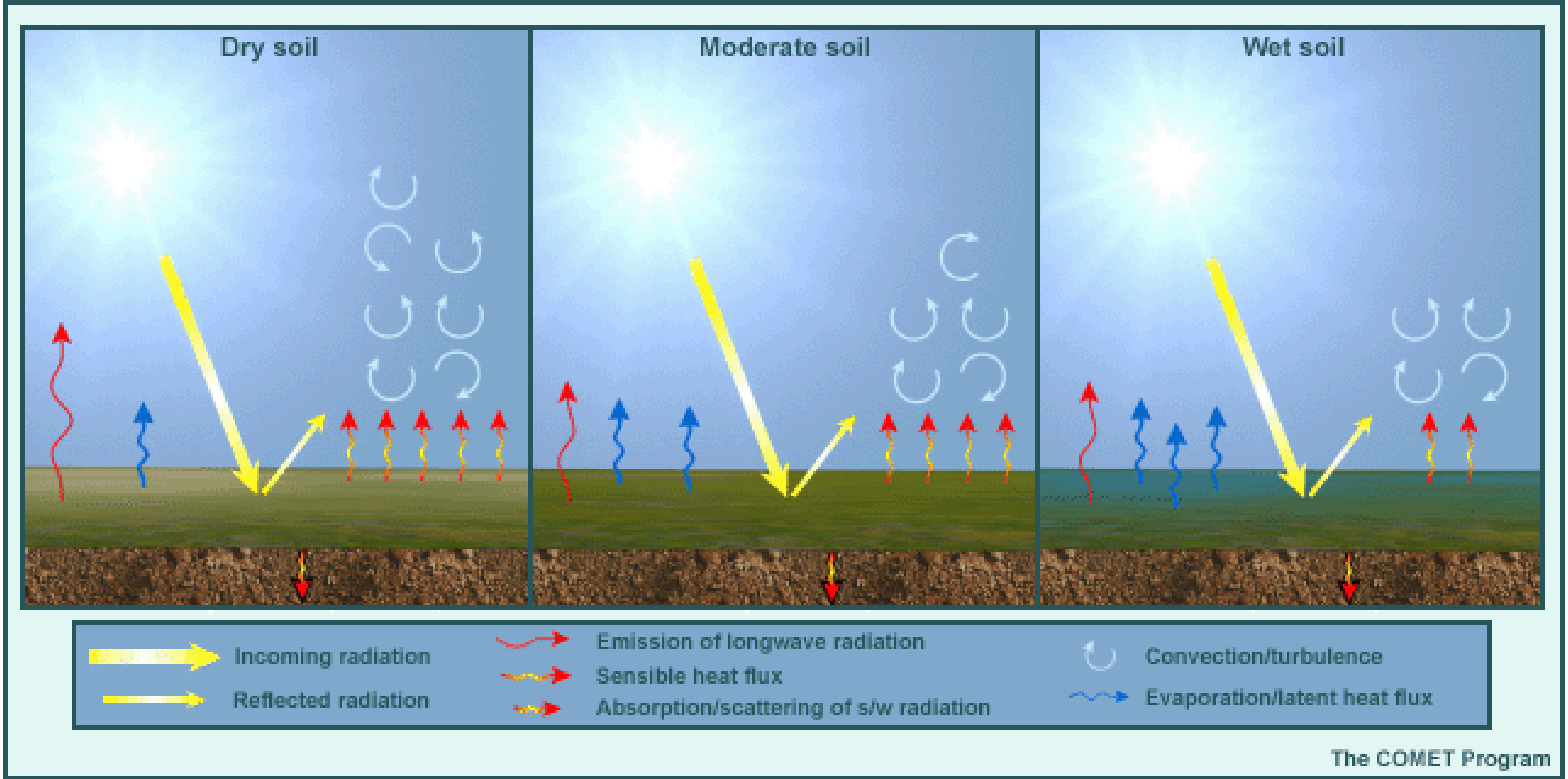
$$E_{eq} = (\varepsilon / \rho\, \lambda\, (\varepsilon + 1))\, R_n \qquad 2.6$$

- ζ (zeta) is a combination of constants and easily measured variables

$$\zeta = \rho\, (\varepsilon + 1)\, G_v\, T_k$$

$$E = E_{eq} + D\, g_b / \zeta \quad 2.5$$

- E_{eq} Evaporation rate at equilibrium
- D Air saturation deficit
  - Warm dry air near the surface will increase this value increasing evaporation
- g_b Boundary layer conductance
  - Small values (low conductance) will make surrounding air conditions less important and make evaporation more similar to equilibrium conditions


Dry soil
Moderate soil
Wet soil
Incoming radiation
Reflected radiation
Emission of longwave radiation
Sensible heat flux
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Pictures from:

http://www.meted.ucar.edu/nwp/model_physics/print.htm