Principles of Energy Balance in Environmental Systems

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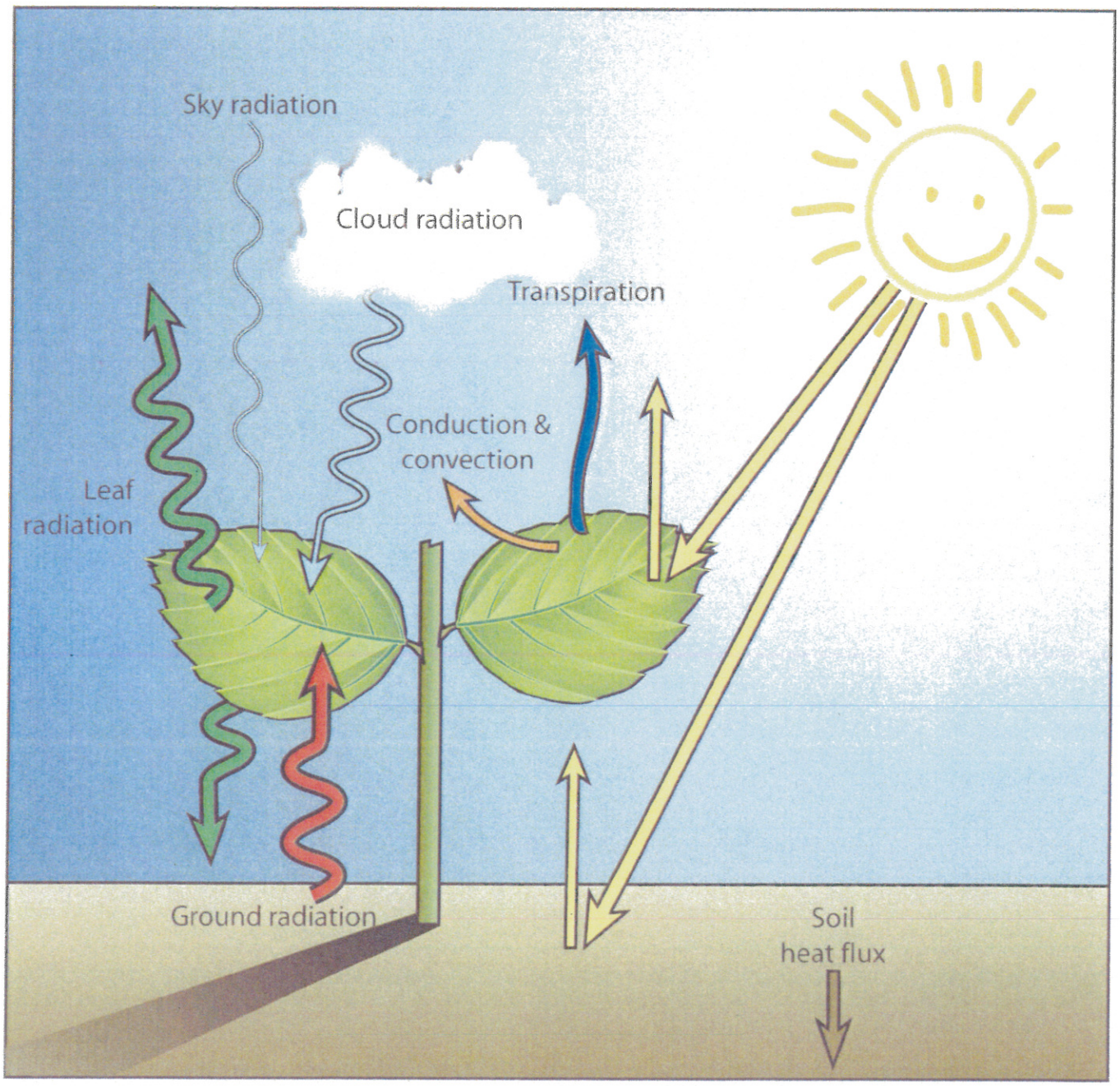
Lecture 3

1. The concept of emissivity
2. Calculating long wave emitted
3. Calculating net longwave radiation
4. Calculating net absorbed short and longwave radiation

Components of Energy Balance for a plant



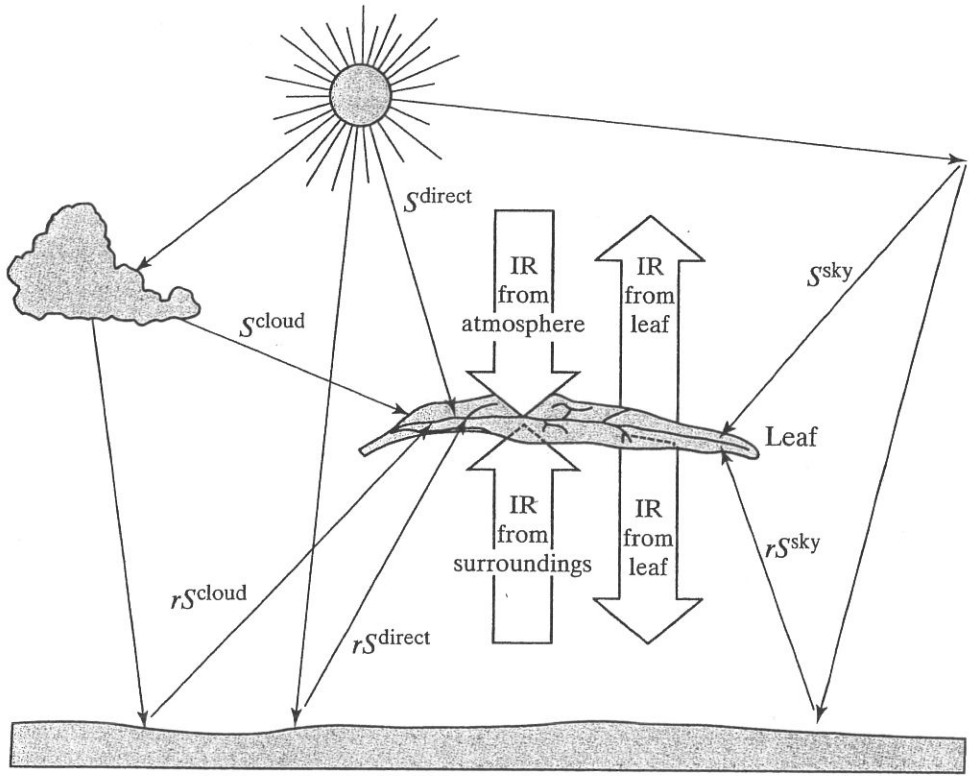
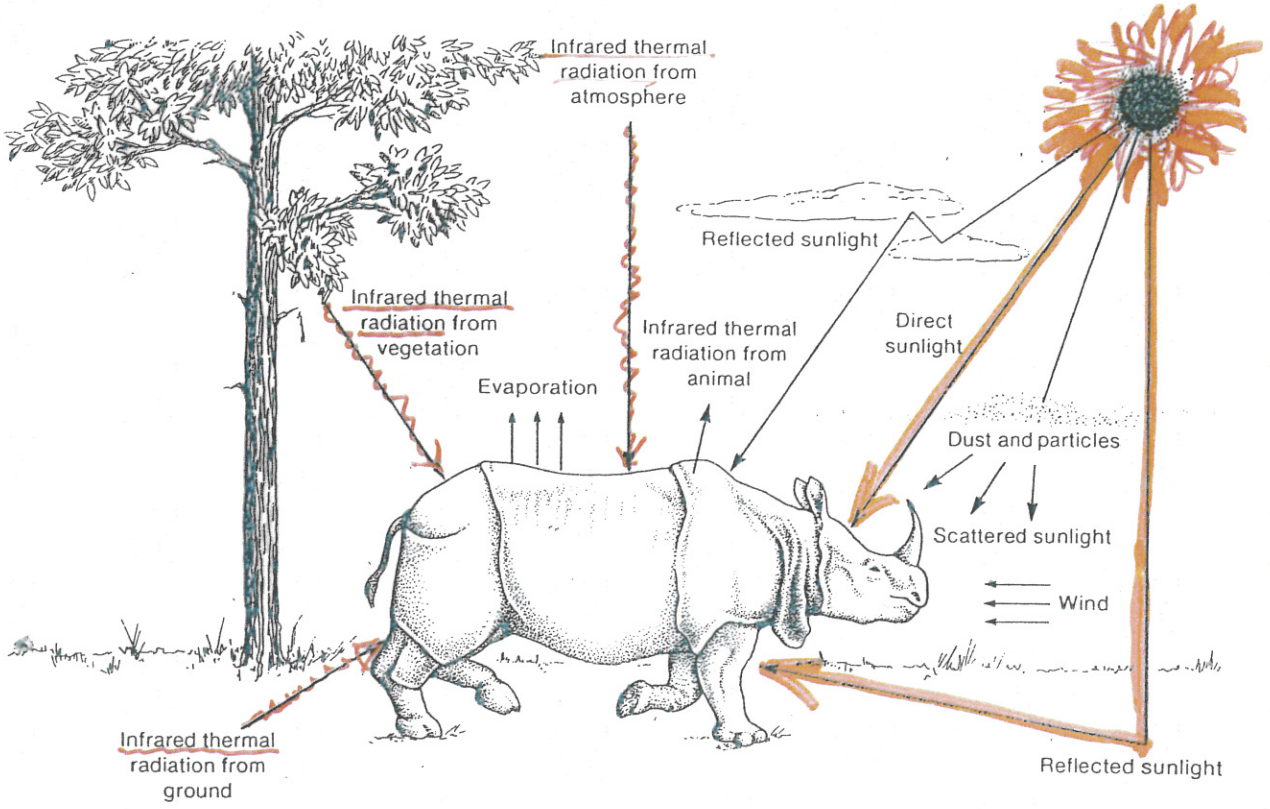


Figure 7-1. Schematic illustration of eight forms of radiant energy incident on an exposed leaf, including six that involve shortwave irradiation from the sun and contain the letter S and two that involve infrared (IR) radiation incident on the upper and the lower leaf surfaces. Also illustrated is the IR emitted by a leaf.



16-16 Channels of heat transfer between an animal and its environment. [Modified from Porter and Gates, 1969.]

Man

The radiation and heat balance of men working in Antarctica were studied by Chrenko and Pugh (1961), and Fig. 12.8 is based on their analysis for a man wearing a black sweater standing facing the sun. The air temperature was only −7.5°C but, because the sun was 22° above the horizon, the radiative load on vertical surfaces facing the sun was exceptionally large. As the wind was light, r_{HR} was relatively large, about 1 s cm^{-1}. The top left-hand side of the diagram, referring to the sunlit chest, was constructed from measured

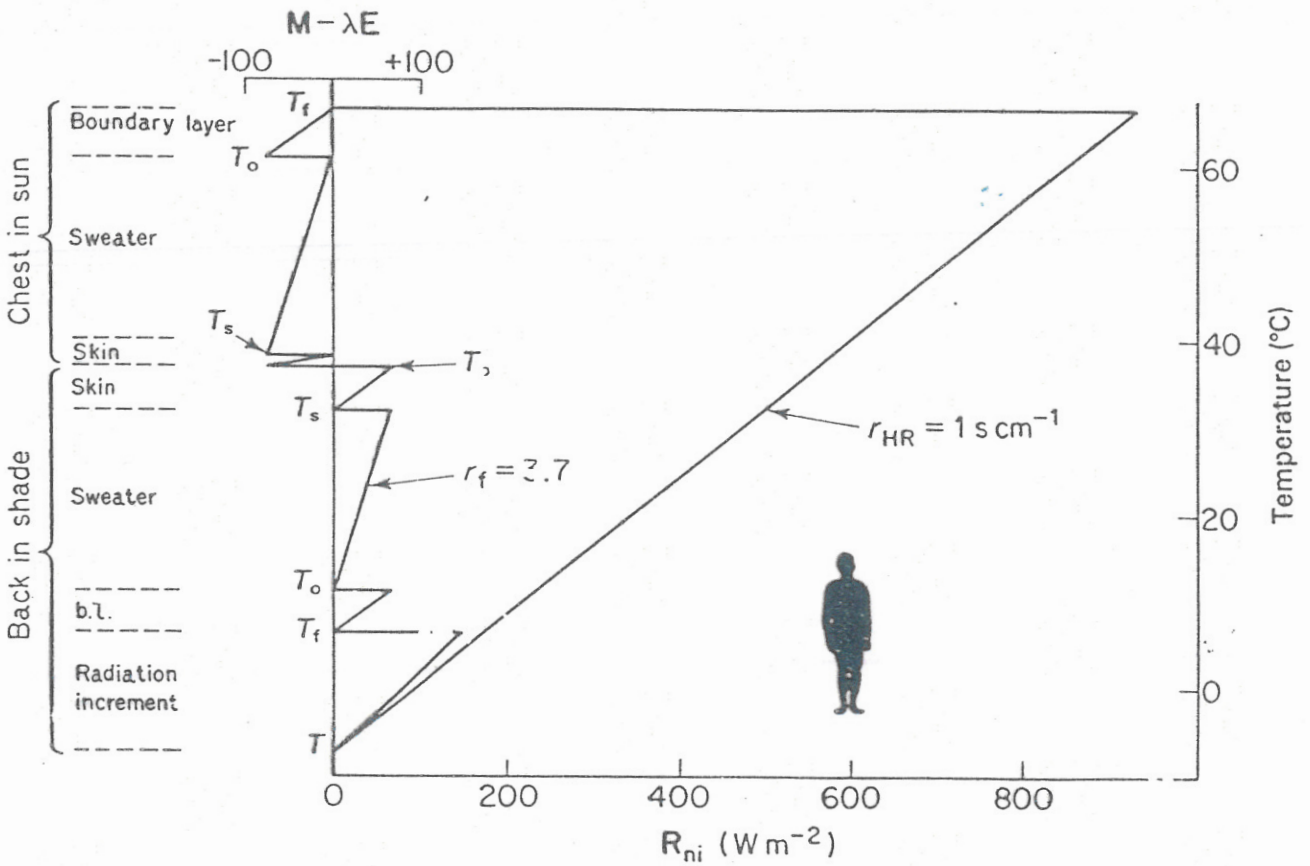


Fig. 12.8 Temperature/heat-flux diagram for a man wearing a black sweater exposed to arctic sunlight and air temperature of −7°C. The lower part of the diagram shows the equivalent temperature and sweater surface temperature on his back (in shade) and the upper part shows the same temperature on his chest (in full sun).

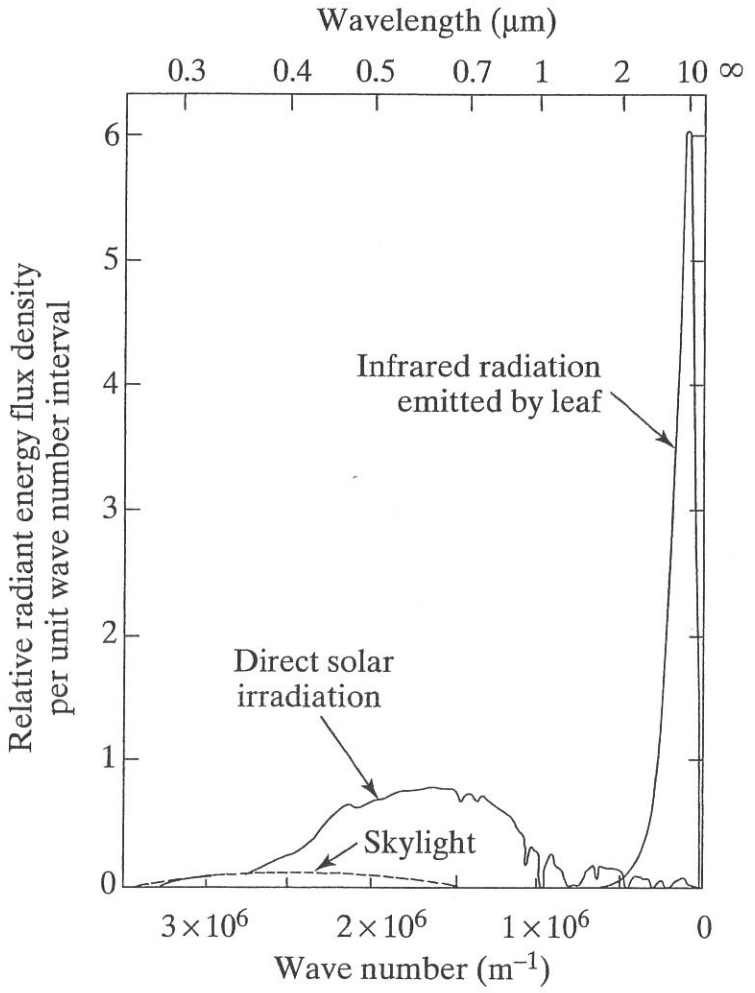


Figure 7-2. Wave number and wavelength distributions for direct solar irradiation, skylight, and radiation emitted by a leaf at 25°C. Wave number (introduced in Problem 4.2) equals the reciprocal of wavelength and thus is proportional to energy (see Eq. 4.2a; $E_\lambda = h\nu = hc/\lambda_{vac}$). The areas under the curves indicate the total energy radiated: S^{direct} is 840 W m^{-2}, S^{sky} is 80 W m^{-2}, and the IR emitted is 860 W m^{-2}.

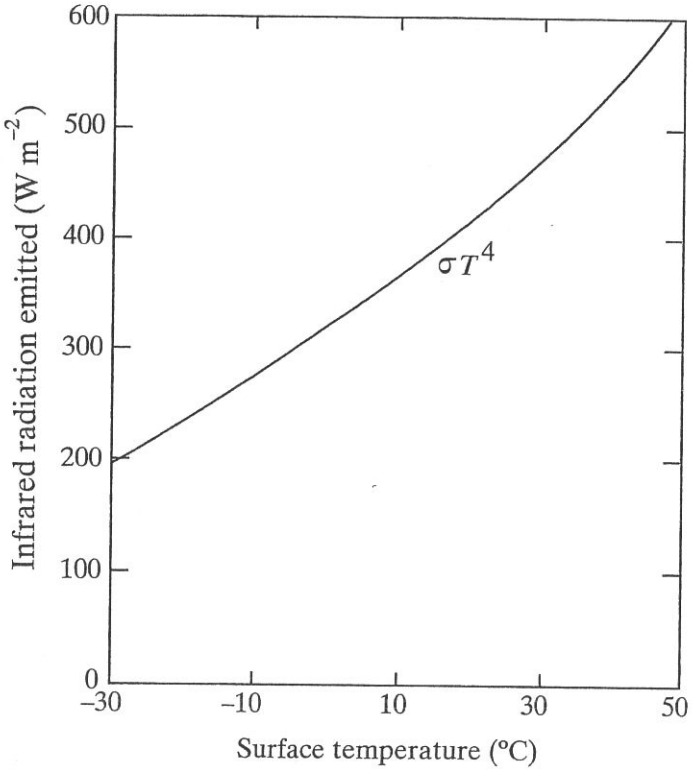
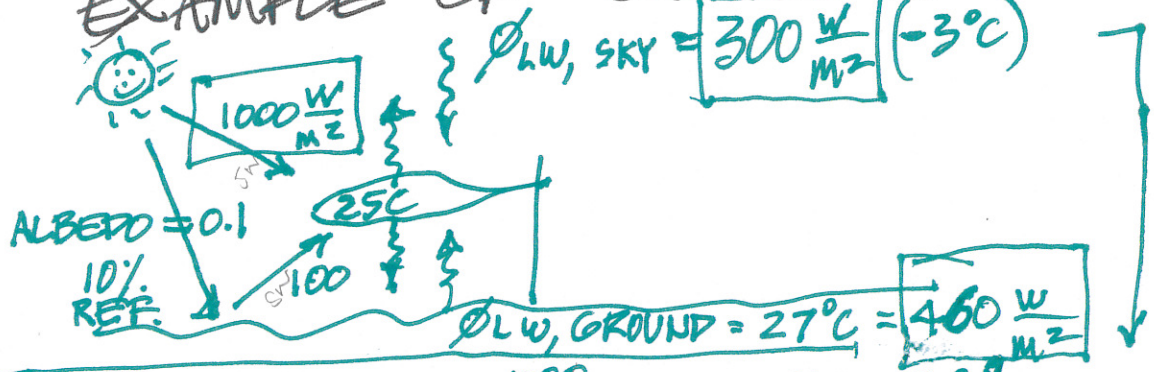


Figure 7-3. Rate of emission of infrared (longwave) radiation per unit area by a blackbody ($e_{IR} = 1.00$) versus its surface temperature, as predicted by the Stefan–Boltzmann law (Eq. 6.18).

SINGLE LEAF ENERGY BALANCE

EXAMPLE OF CALCULATIONS



ϕ_{SW} = 1000 + 100 = 1100

50% ABSORBED × .5

$\phi_{SW, ABSORBED}$ = 550

EMISSIVITY 0.9 × 0.9

414 W/m²

$\phi_{LW, INCIDENT}$ 300 + 414 = 714

LEAF ABSORBTIVITY 0.96

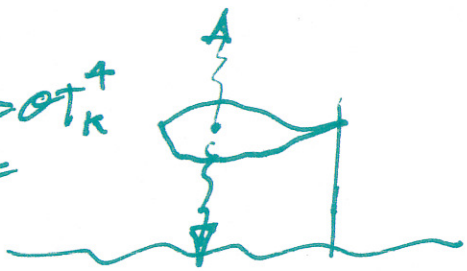
$\phi_{LW, ABSORBED}$ = 685 W/m²

$\phi_{TOTAL, ABSORBED}$ 550 ϕ_{SW} + 685 ϕ_{LW} = 1235 W/m²

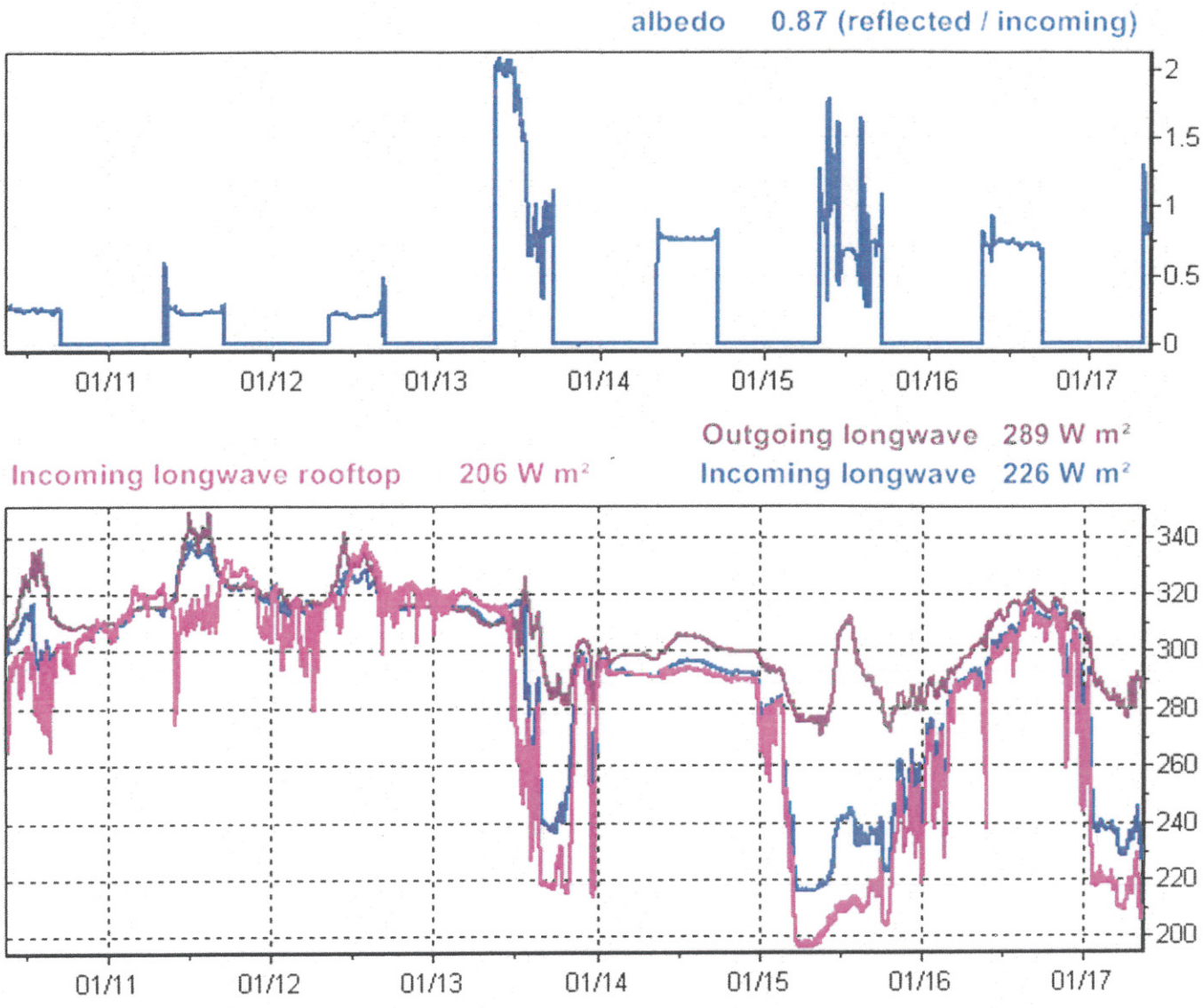
$\phi_{emitted}$ 25°C = 448 W/m² (FROM $E = \sigma T_K^4$)

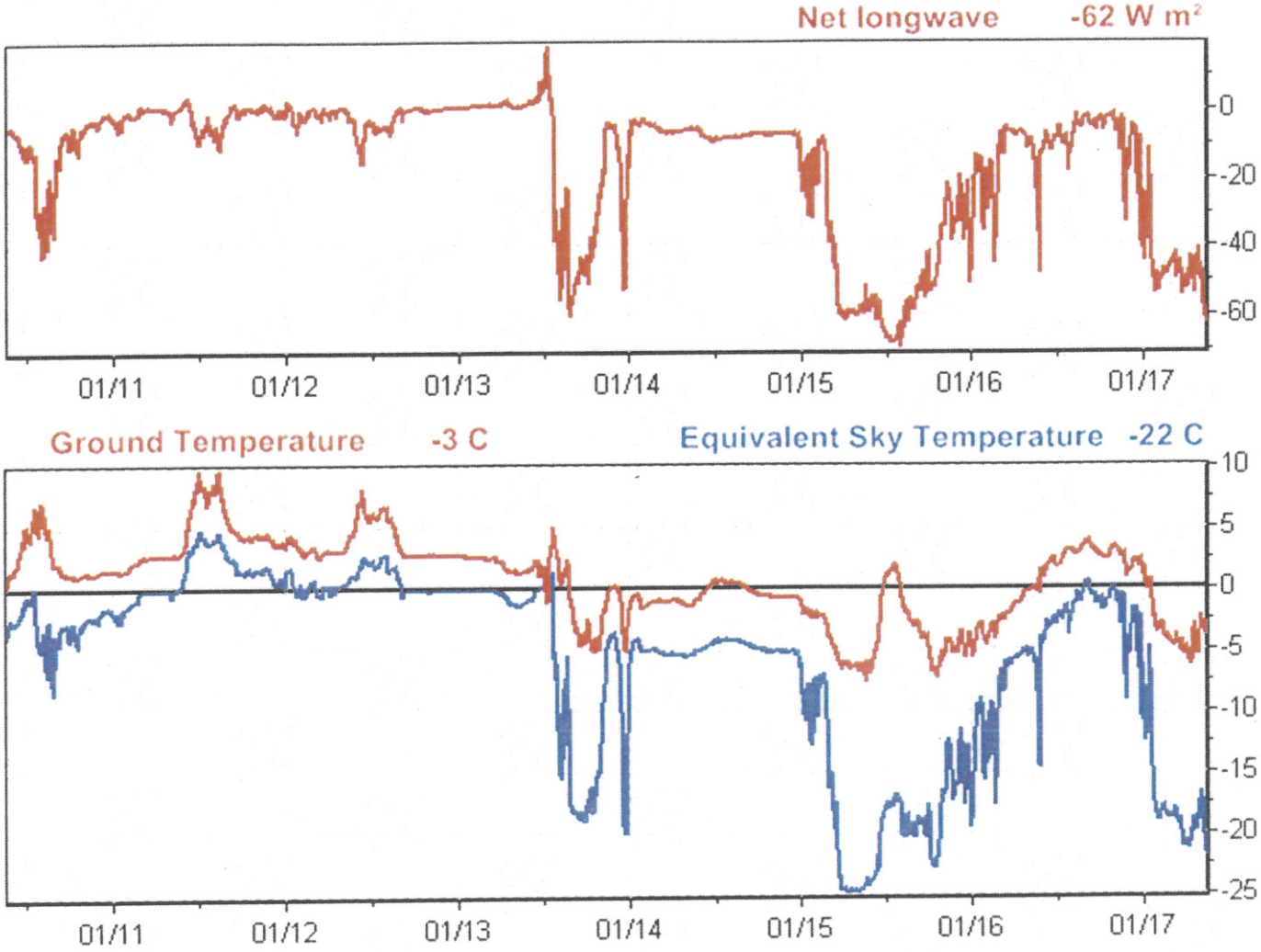
× 2 SIDE OF LEAF = 896

LEAF EMISSIVITY 0.96 = 860 W/m²



R_{net} (ϕ_{net}) = $\phi_{ABSORBED} - \phi_{emitted}$ = 1235 − 860 = **375 W/m²**

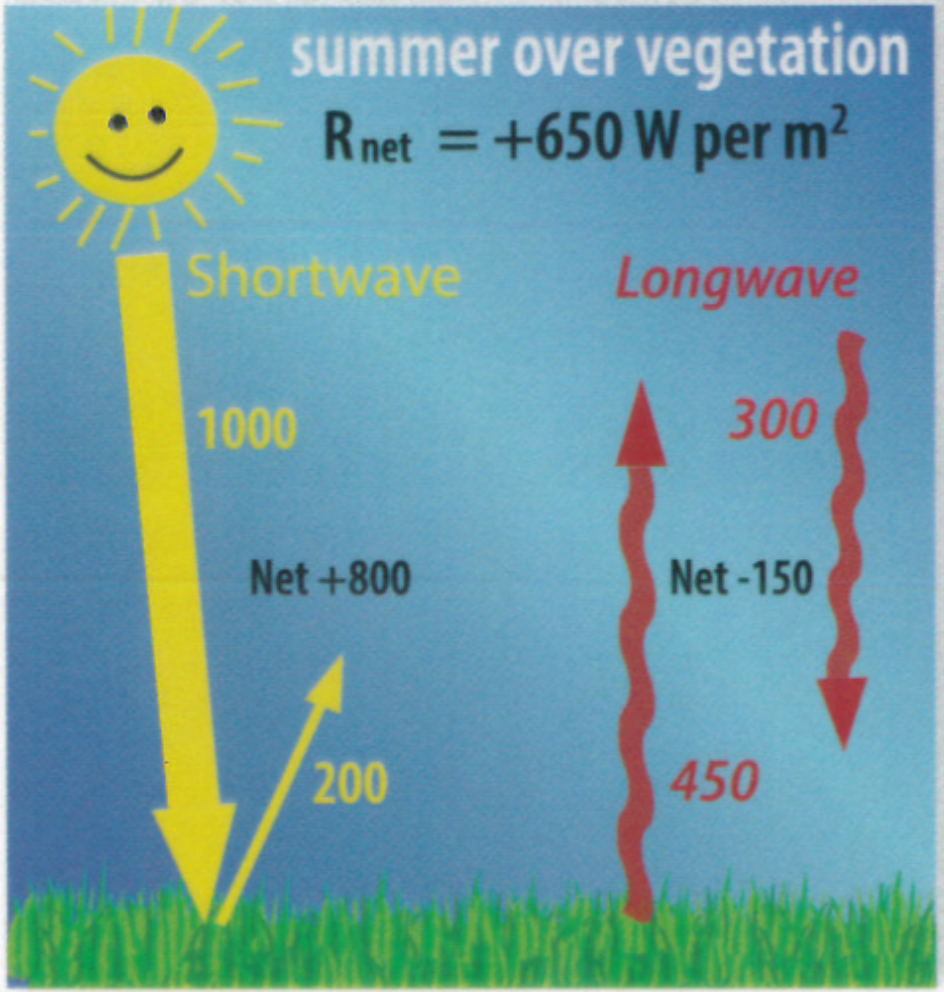

albedo 0.87 (reflected / incoming)
2
1.5
1
0.5
0
01/11
01/12
01/13
01/14
01/15
01/16
01/17
Outgoing longwave 289 W m²
Incoming longwave 226 W m²
Incoming longwave rooftop 206 W m²
340
320
300
280
260
240
220
200
01/11
01/12
01/13
01/14
01/15
01/16
01/17

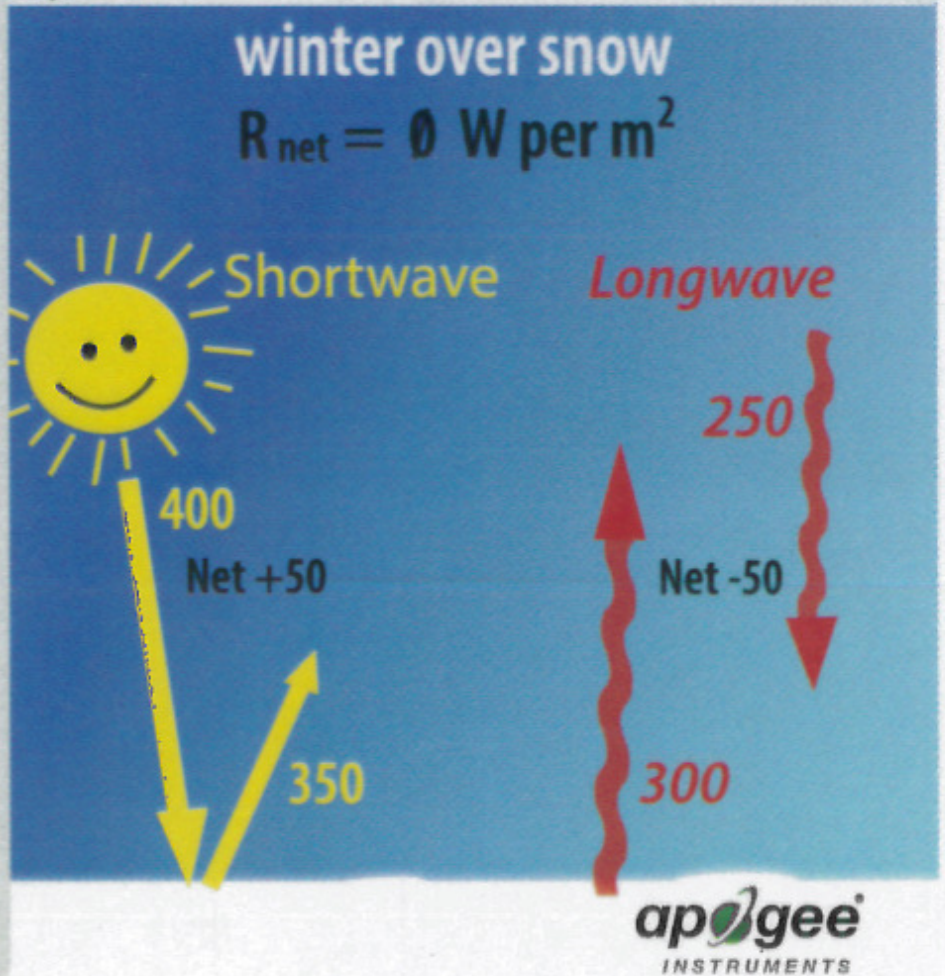


Hukseflux NR01 4-way
Net Radiometer

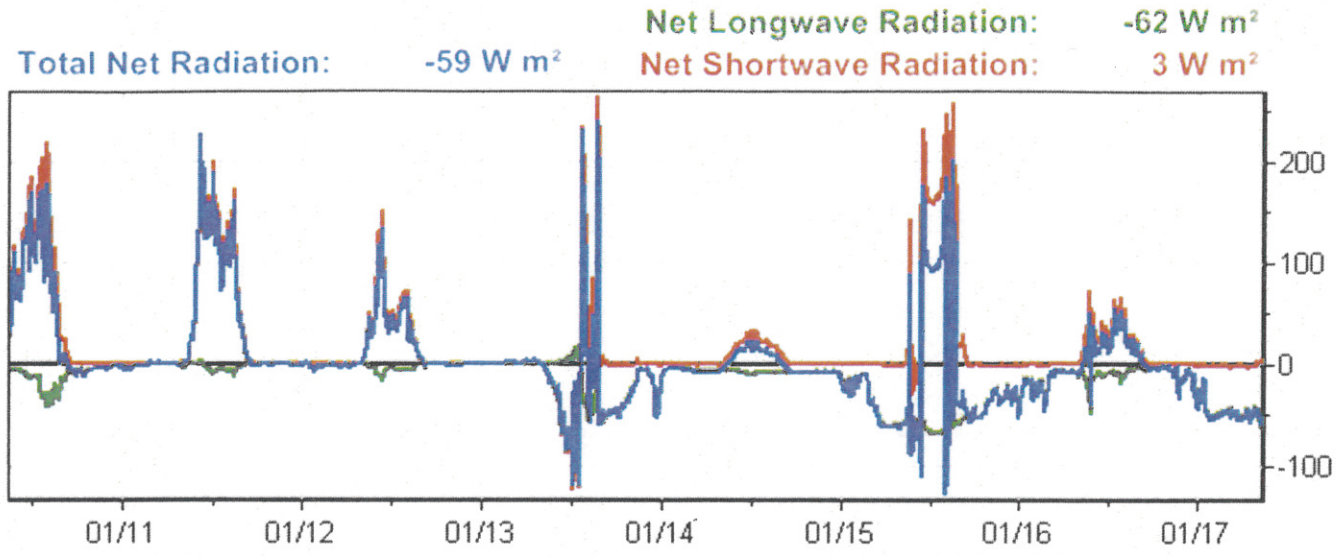
Typical Radiation Fluxes

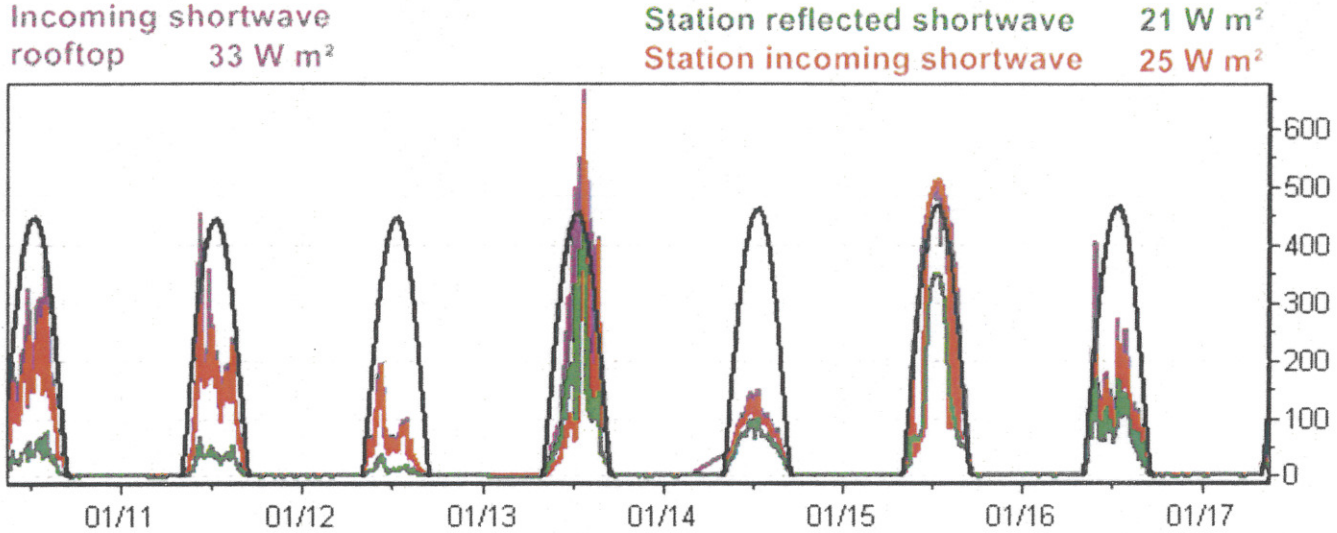
at solar noon for clear sky conditions





apogee INSTRUMENTS

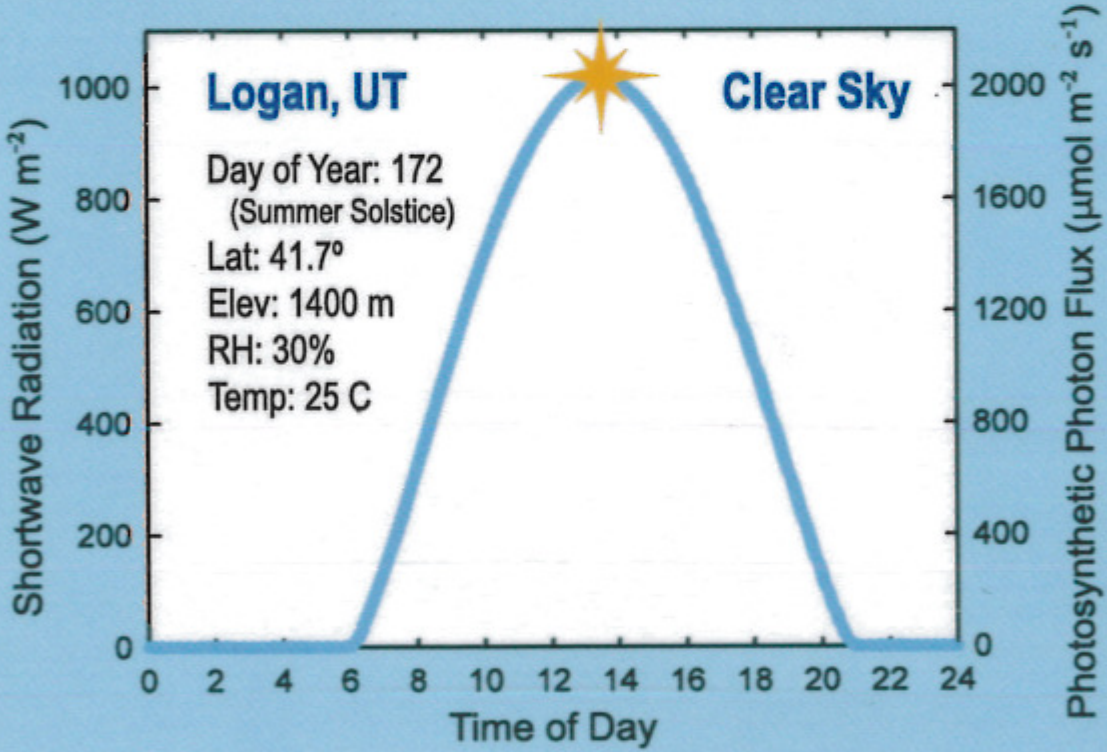

Net Longwave Radiation: -62 W m²
Total Net Radiation: -59 W m²
Net Shortwave Radiation: 3 W m²
200
100
0
-100
01/11
01/12
01/13
01/14
01/15
01/16
01/17


Incoming shortwave
rooftop 33 W m²
Station reflected shortwave 21 W m²
Station incoming shortwave 25 W m²
600
500
400
300
200
100
0
01/11
01/12
01/13
01/14
01/15
01/16
01/17

Clear Sky CALCULATOR

Calculate radiation intensity at any location in the world to determine the need for radiation sensor recalibration.

www.clearskycalculator.com



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