# Physical Climatology Problem Set #3
(for Undergrads)

Refer to Figure 2.4 page 28.

(1) $S\downarrow = ?$, $S\uparrow = ?$, $L\downarrow = ?$, $L\uparrow = ?$ } at the earth's surface.

Assume the atmosphere (e.g. both stratosphere and troposphere) reflects the same amount of solar radiation as does the surface.

we have $S\uparrow = 30/2 = 15$ units $= 15 \times \frac{342}{100} = 51.3\ Wm^{-2}$

$S\downarrow$ = Solar radiation at the top of the atmosphere
- solar radiation absorbed within the stratosphere
- solar radiation absorbed with the troposphere
- solar radiation reflected by the atmosphere

$= 100 - 3 - 17 - (30/2) = 65$ units $= 65 \times \frac{342}{100} = 222.3\ Wm^{-2}$

$L\downarrow = 89$ units $= 89 \times \frac{342}{100} = 304.38\ Wm^{-2}$

$L\uparrow = 110$ units $= 110 \times \frac{342}{100} = 376.2\ Wm^{-2}$

(2) The surface albedo $= \frac{S\uparrow}{S\downarrow} = \frac{51.3}{222.3} = 23\%$

(3) $Rnet = (S\downarrow - S\uparrow) + (L\downarrow - L\uparrow) = (222.3 - 51.3) + (304.38 - 376.2)$
$= 99.18\ Wm^{-2}$

$SH + LE = 5 + 24 = 29$ units $= 29 \times \frac{342}{100} = 99.18\ Wm^{-2}$

$\therefore$ $Rnet = SH + LE$ The net radiation at the earth's surface is balanced by turbulent fluxes (i.e. sensible and latent heat fluxes).

(4) The Bowen ratio $B = \frac{SH}{LE} = \frac{5}{24} = 0.208$

(5) $E = ?$ mm/day

$LE = 24$ units $= 24 \times \frac{342}{100} = 82.08\ Wm^{-2}$

From Appendix 6, page 374, we find the latent heat of vaporization at 0°C

$L = 2.5 \times 10^6\ J\,kg^{-1}$

$\therefore E = \frac{LE}{L} = \frac{82.08\ Wm^{-2}}{2.5 \times 10^6\ J\,kg^{-1}} = 3.2832 \times 10^{-5}\ kg\,m^{-2}\,s^{-1}$

$= 3.2832 \times 10^{-5}\ mm\,s^{-1}$

$= 3.2832 \times 10^{-5} \times 86400$ mm/day

$\doteq 2.84$ mm/day

Note in the derivation, we have used

$1\ kg\,m^{-2} = 1\ mm$ for water

and $1$ day $= 24$ hours

$= 24 \times 60$ minutes

$= 24 \times 60 \times 60$ seconds

$= 86400\ s$