

WEEK 1:
ENERGY BUDGET NEAR THE SURFACE
Homework assignment

Read Chapter 2 of *Introduction to Micrometeorology*, by Arya, which contains useful example problems.

Problems:

1. *List two factors that control the value of the Bowen ratio. Describe the conditions when you would expect the Bowen ratio to be*

- (a) much less than 1
- (b) much greater than 1
- (c) negative

2. Over a moist land surface the Bowen ratio is estimated to be approximately 0.4. *Estimate the direct (sensible) and indirect (latent) energy fluxes to the atmosphere from the surface.* The net radiation entering the surface is 800 W m^{-2} and the heat flux to the ground below is 100 W m^{-2} .

Now consider the same Bowen ratio and net radiation, but with a soil layer of finite depth rather than an infinitesimally-thin surface. The heat flux to the soil below 50 m is negligible, and the mean rate of warming of the upper 50 m of soil is $0.1 \text{ }^{\circ}\text{C day}^{-1}$. The heat capacity of the soil is $1480 \text{ J K}^{-1} \text{ kg}^{-1}$ and the soil density is 1500 kg m^{-3} . *What are the sensible and latent heat fluxes from the soil to the air in this case?*

Given that the latent heat of evaporation of water $L_e = 2.5 \times 10^6 \text{ J kg}^{-1}$, what is the rate of evaporation of water (in mm day^{-1}) in each case?

3. *What would be the rate of warming of a 50 m deep ocean mixed layer if the evaporation rate is 10 mm day^{-1} , the net radiation loss from the surface is 50 W m^{-2} , and the Bowen ratio is 0.25.* This is similar to conditions in cold air outbreaks in winter as cold continental air is advected over a much warmer, adjacent ocean or large lakes. Due to the intense evaporation of water from the surface, cold air outbreaks can bring intense snow to regions immediately downwind of the Great Lakes (e.g. Buffalo, NY).

4. Describe likely conditions that would be responsible for

- (a) a boundary layer that is 3 km deep
- (b) a boundary layer that is 50 m deep

