Homework #3
Radiation and Turbulence

NOTE: On all quantitative answers, give the appropriate SI units!

1. Consider the radiative interplay between the sun and the earth.

   a. Given that the solar constant is 1380 W m^{-2}, and the mean earth-sun distance is $1.50H10^{11}$ m, what is the total flux from the sun in Watts?

   b. What fraction of all sunlight emitted by the sun is intercepted by the earth (the radius of the earth is $6.37H10^{6}$ m)?

   c. Calculate the equivalent blackbody temperature of the earth, assuming a planetary albedo of 0.30 (the planetary albedo is the fraction of the total incident solar radiation that is reflected back into space by soil, plants, ocean, snow, clouds, etc., without absorption). Assume that the earth is in radiative equilibrium, so that there is no net energy gain or loss due to radiation.

   d. Assume the planet earth has a thin (relative to the radius of the earth) isothermal atmosphere which is transparent to solar radiation, but has an absorptivity of 0.5 for longwave radiation. The planetary albedo is simply the surface albedo. What are the radiative equilibrium temperatures of the atmosphere and surface in this situation? Has the equivalent blackbody temperature of the earth-atmosphere system changed from Part *c*? Why?

   e. Repeat the calculation in Part *d* for atmospheric longwave absorptivities of 0.75 and 1.0. Explain why the temperatures change in this manner.

   f. For the last case (A_{ATM} = 1.0) change the surface albedo to 0.5. What happens to the temperatures of the atmosphere and surface?

   g. What is the wavelength 8_{MAX} of maximum emission for a body at the earth's equivalent blackbody temperature (assume an emissivity of 1)?

   h. What is the monochromatic flux density for earth at 8_{MAX}?

   i. What is the monochromatic flux density of the sun at that same wavelength (assume the sun is a blackbody at a temperature of 5780 K)?

2. Imagine three biomes representing tropical forest, deforestation (degraded tropical shrubland) and complete desertification (no vegetation). They have the following properties with respect to <u>solar</u> radiation:

	Reflectivity ***R***	Transmissivity ***T***	Absorptivity ***A***
Tropical forest	0.1	0.1	0.8
Degraded shrubland	0.2	0.4	0.4
Bare soil	0.25	0.0	0.75

Also note that the same bare soil also underlays the forest and the shrubland. For simplicity, assume radiative emissivity = 1 for all surfaces.

Downward solar radiation (shortwave radiation) over all three biomes is 1000 Wm^{-2}.

Using the plane-parallel two-stream approximation for radiative transfer, calculate for <u>each</u> of the three biomes:

a. the total shortwave radiation absorbed at the soil surface (units of Wm^{-2})

b. the total shortwave radiation absorbed by the canopy (also in units of Wm^{-2})

c. the net surface albedo (combining effects of both vegetation and soil).

You will have to follow the transmissions and reflections of radiation between canopy and ground until you reach a precision in your answers of 1 Wm^{-2}.

3. You know the following conditions at the top of the constant stress layer:

   z=10 m, u=5 m s^{-1}, 2=290 K, q=0.010 kg/kg, D=1.1 kg m^{-3}:

   a. The roughness length z_o = 0.5 m. What is the frictional velocity?

   b. What is the drag coefficient?

   c. Given that the roughness length for heat and moisture is 0.3 m, what is C_H ?

   d. What are the aerodynamic resistances for momentum and heat?

   e. At the bottom of the constant stress layer the potential temperature is 292 K. What is the sensible heat flux across the layer, and in what direction? (c_p=1010 J kg^{-1} K^{-1})

   f. What specific humidity q_o would be necessary for the latent heat flux to equal the sensible heat flux? (Note: you must multiply E_o by the latent heat of vaporization 2.45H10^6 J kg^{-1} to compare them).