WEEK 3/4:
SOIL TEMPERATURE and AIR TEMPERATURE/HUMIDITY
Homework assignment

Read Chapters 4 and 5 of *Introduction to Micrometeorology,* by Arya, which contains useful example problems.

Problems:

1. *What are the key reasons why the subsurface temperature structure of soils is markedly different to that of water bodies?*

2. Measurement of the surface skin temperature of bare soil. The sensible heat flux is 300 W m^{-2} and the ground flux 40 W m^{-2}. *Estimate the temperature gradients near the surface in the air and the soil given that the thermal conductivity k=0.03 W m^{-1} K^{-1} in air and 0.4 W m^{-1} K^{-1} in the soil.* Given this information, would you choose to make measurements in the air or soil to find the skin temperature by extrapolation?

3. Given the information in Table 4.1 of Arya (see Arya slides on the resources link on the class webpage), *calculate the damping depth d for an ice sheet for a diurnal wave and an annual wave*. The annual ice accumulation due to falling snow on the Greenland ice sheet is 5.1×10^{14} kg yr^{-1} over an area of 1.6×10^{6} km^2. *What is the annual rate of addition of new ice in terms of depth per year?* The density of ice can be assumed to be 900 kg m^{-3}. Discuss possible implications for the ability to observe the diurnal and annual thermal waves.

4. The Figure on the right shows measured monthly mean temperature as function of depth below the snow surface of an extensive ice sheet (from Brandt and Warren, *J. Glaciology*, **43**, 144, 1997). Note that not every month is present.

(a) *Is the data taken from a snow surface at Greenland or at the South Pole?*

(b) *Estimate the annual temperature range at the surface and at a depth of 3 m. Given what you have learned about how the amplitude of the temperature response changes with depth, give an approximate estimate the penetration depth d.*

(c) The mean density of the snow was measured to be 360 kg m^{-3} and the specific heat *c* of pure ice is 2.1×10^{3} J kg^{-1} K^{-1}. *Use your estimate of the penetration depth to estimate the mean thermal conductivity of the snow.* Show how you made this estimate.

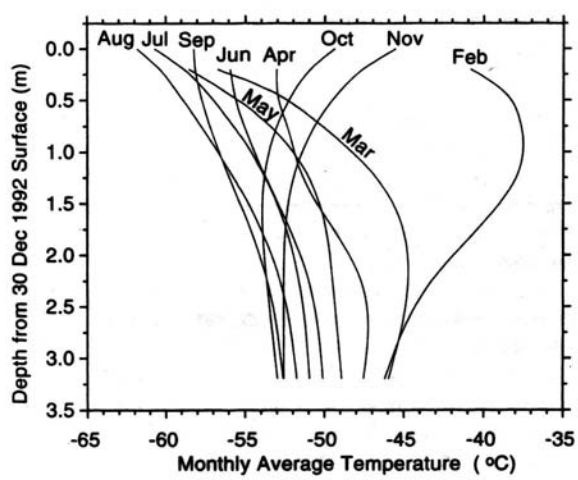

Fig. 5. Monthly average snow-temperature profiles for February through November 1992. The annual average 2 m air temperature is −49.3°C. (Schwerdtfeger, 1977); the snow temperature at 10 m depth is −50.9°C (Dalrymple, 1966).

Do you think the heat capacity of the air in between the snow grains is important?

(d) From these data the authors were able to estimate the thermal conductivity *k* as a function of depth. This is shown in the figure below (solid squares with error bars). *Why do you think that the conductivity might be reduced near the surface?* (Bear in mind that all the snow below the depth (≈0.5 m) where the conductivity becomes constant has experienced a whole summer).

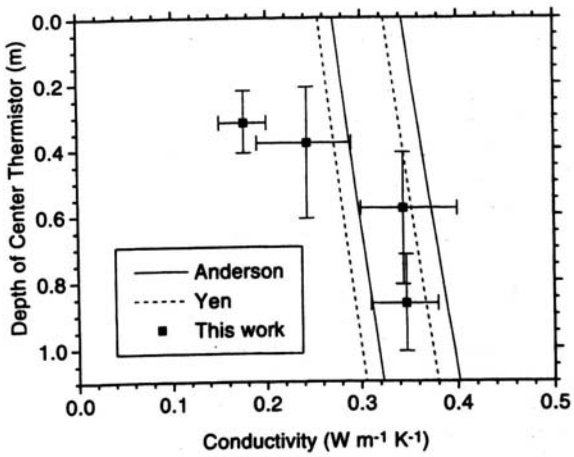

Fig. 11. Average conductivity of each thermistor group as a function of depth. Error bars indicate the range of modeled conductivity and range of depths of the center thermistor for all periods. Lines indicate parameterizations based on density (Equations (9) and (10)), using densities one standard deviation above and below the measured values shown in Figure 2.

5. *Explain why the saturated adiabatic lapse rate is less than the dry adiabatic lapse rate.* Under what conditions would you expect the largest and smallest deviations of the saturated lapse rate from the dry one? What does this imply for the climatological distribution of Foehn winds.