**Atmos 5300**
**Exercise on Turbulent Fluxes**

1. The surface sensible heat flux $F_s = \rho c_p \overline{w'T'} = 1000$ W m$^{-2}$ and the atmospheric boundary layer (ABL) depth $h = 500$ m. How much does the average ABL temperature change during 3 h? Use $\rho = 1.2$ kg m$^{-3}$.

2. Same as problem 1 but in this case $F_s = -50$ W m$^{-2}$ and $h = 50$ m.

3. 1 cm of water evaporates from the ocean into an ABL that is 500 m deep.
   (a) What is the change in the average ABL water vapor mixing ratio (mass of water vapor per unit mass of dry air), $\Delta q$? Use $\rho = 1.2$ kg m$^{-3}$.
   (b) If this process occurs over 4 h, what is the average surface flux of water vapor, $F_q = \rho \overline{w'q'}$?
   (c) What is the latent heat flux, $LF_q$? $L = 2.5 \times 10^6$ J kg$^{-1}$ is the latent heat of vaporization.

4. The turbulent momentum flux components are $\overline{u'w'} = -0.1$ m$^{-2}$s$^{-2}$ and $\overline{v'w'} = 0$.
   (a) What is the friction velocity, $u_*$? [WH Eq. 9.14]
   (b) What is the magnitude of the surface stress? Use $\rho = 1.2$ kg m$^{-3}$.[WH Eq. 9.14]
   (b) If $h = 500$ m, how much would the *vertical averages* of the horizontal velocity components, $\bar{u}$ and $\bar{v}$, change over 6 h *due to the surface stress alone*? Assume that the wind velocity and surface stress vectors are parallel. [The governing equations for $\bar{u}$ and $\bar{v}$ are given on slide 31 (of 39) of
   `https://www.inscc.utah.edu/~krueger/5220/WH-ABL-2.pdf`.]
   (c) What additional forces act to maintain the ABL wind?