ESS 5203: Turbulence and Diffusion in the Atmosphere

Assignment #3 Due March 16

1) Winds have been blowing strongly from due W over Lake Erie for several days. Wind stress on the surface is 0.2 Nm^{-2}. Ignore any coastal effects, Assume horizontal homogeneity, no surface slope and a well-mixed surface layer with a very strong thermocline at a depth of 5m. Assume f = 10^{-4} s^{-1}. In the simplest, idealized case with no mixed layer deepening, what currents would you expect in that upper mixed layer? Suppose that the wind suddenly stops blowing. What happens to the currents? Explain the idealizations that you make.

2) Download the "Assignment3_Data.txt" file, which contains data recorded by a sonic anemometer and a co-located, open-path CO_2 analyzer at a height of 33 m above the ground. The data were recorded at a frequency of 10 Hz. The columns are wind speeds *u*, *v*, *w*, [m/s], air temperature *T* [^oC], and CO_2 concentration [mol/m^3] where *u* is aligned to be positive for a southerly wind.

a) Perform a rotation of the coordinates around the z axis and then the y axis, so that $\overline{v}$ and $\overline{w}$ are zero. What is the final value of $\overline{u}_r$ (the mean rotated u component of the wind speed)? What are the angles of rotation, θ and η? From what direction is the wind speed?
b) Calculate all relevant moments, variances and co-variances of the time series, including $\overline{u_i}, \overline{u_i'^2}, u_*$, TKE, H_0, and the CO_2 flux.
c) Perform an auto-correlation of the rotated wind speed. Demonstrate the estimation of a time and length scale of the turbulence on a graph of ρ_u versus τ.
d) Calculate the spectra of the variance of the rotated wind, $S_{u^2}(f)$. Present the results as two log-log graphs: one in raw units of m^2/s versus Hz, and one with scaled axis $fS_{u^2}(f)/\overline{u'^2}$ versus $fz/\overline{u}$. On each graph, identify the peak frequency and demonstrate the Kolmogorov power-law decay in the inertial subrange and the "slope" of the curve at very low frequencies.

Note: The spectrum, $S(f)$, of a variable (e.g. u or u') is calculated by taking the magnitude-squared FFT of the time series. If the time series has n points, the FFT has $n/2$ points (i.e. the positive side only). The frequency of the FFT ranges from 0 for the first point (the mean) to $f_r/2$, where f_r is the instrument frequency.