Atm Sci 547 Due Thursday 12 April, 2018

Homework Set 1

The dataset `rf18L1.txt` downloadable from the class WWW page contains 1819 seconds (30 mins) of data from a horizontal aircraft leg flown in a large circle S of Australia 30 meters above the ocean surface, sampled 25 times per second. The aircraft is flying at speed $U_0 = 100$ m s^{-1}. The columns are labeled; *u*, *v*, *w* are the three velocity components, *T* is temperature and *q* is water vapor mixing ratio, while the last column, *p* (which we won't use) is the measured air pressure. In this problem, we will analyze this dataset using Matlab or Python/matplotlib. Please write a script or scripts (to attach with your solutions) that implements the following:

1. Plot *u*, *v*, *w* vs. time, and note that all of them show mesoscale variability (on scales of 10 km, or 100 s of sampling time) as well as turbulent variability.
2. Perform a spectral analysis of vertical velocity *w* and E-W velocity component *u* using the Matlab signal-processing toolbox function `pwelch` called according to the script `psduw.m` given in the class web page (or use a matplotlib equivalent in Python). This uses a Hanning window for data tapering and averages the tapered periodograms over overlapping intervals of 4096 samples (160 s, corresponding to 16 km, so variability in *w* on wavelengths longer than 16 km is not accounted for). Log-log plot the analyzed *w* and *u* power spectral densities fP_{ww} and fP_{uu} vs. frequency *f* (recall the factor *f* is for visual integration of the power spectrum to give variance with a log scale for *f*) Over what range in frequencies does P_{ww} exhibit a power law behavior with the expected -5/3 exponent? To what eddy length scale does the low end of this frequency range correspond? At the highest frequencies, the spectrum is distorted by the sensor response characteristics.
3. Within this frequency range, Kolmogorov scaling implies that

$$P_{ww} = 0.8\varepsilon^{2/3}\left(\frac{2\pi}{U_0}\right)^{-2/3} f^{-5/3}$$

   The 0.8 constant is empirical. The power of $2\pi/U_0$ converts between power spectra in time and space. Use an eyeball fit to estimate the proportionality constant *C* between P_{ww} and $f^{-5/3}$ in the inertial range and then use this equation to estimate TKE dissipation rate ε.
4. We isolate the turbulent component of the signal from its mesoscale component by high-pass filtering to remove frequencies of less than 0.05 s^{-1} (wavelengths longer than 2 km) using a Butterworth filter. Download the script `highpassw.m` and use it to perform this filtering on *w*. What is the standard deviation (Matlab function std) of whi, the filtered *w*?
5. The Matlab function `w_lag = xcov(whi,'coeff')` calculates the autocorrelation sequence of the `whi` time series. If `whi` includes ns samples, then `w_lag(ns + lag)` will be the autocorrelation of `whi` with lag time `lag`/25 s. Plot the autocorrelation of `whi` vs. lag time for lag times between 0 and 10 s, and calculate the autocorrelation timescale for *w* at which the autocorrelation drops down to 1/*e*. To what characteristic updraft width does this timescale correspond? Compare the same analysis with the unfiltered `w`.
6. After high-pass filtering *u, v, T, q* similarly, calculate their variances, their correlations with *w*, and the corresponding momentum, sensible and latent heat fluxes, and buoyancy flux. Use a nominal air density of $\rho_0 = 1.21$ kg m^{-3}, $C_p = 1004$ J kg K^{-1} and $L_v = 2.5\times10^6$ J kg^{-1} to compute the fluxes. Momentum fluxes are computed as $\rho_0(\overline{u'w'}, \overline{v'w'})$, with units of Pa.