Homework 1 solutions

The Matlab script `hw1.m` on the class web page illustrates one analysis of this problem and created Figure 1.

1. The upper left panel of Fig. 1 shows the unfiltered velocity components, which exhibit significant mesoscale variability on timescales of 100 s (= 10 km) and longer in addition to the high-frequency turbulent variability. This illustrates the difficulty of determining local turbulent fluxes from a horizontal average.

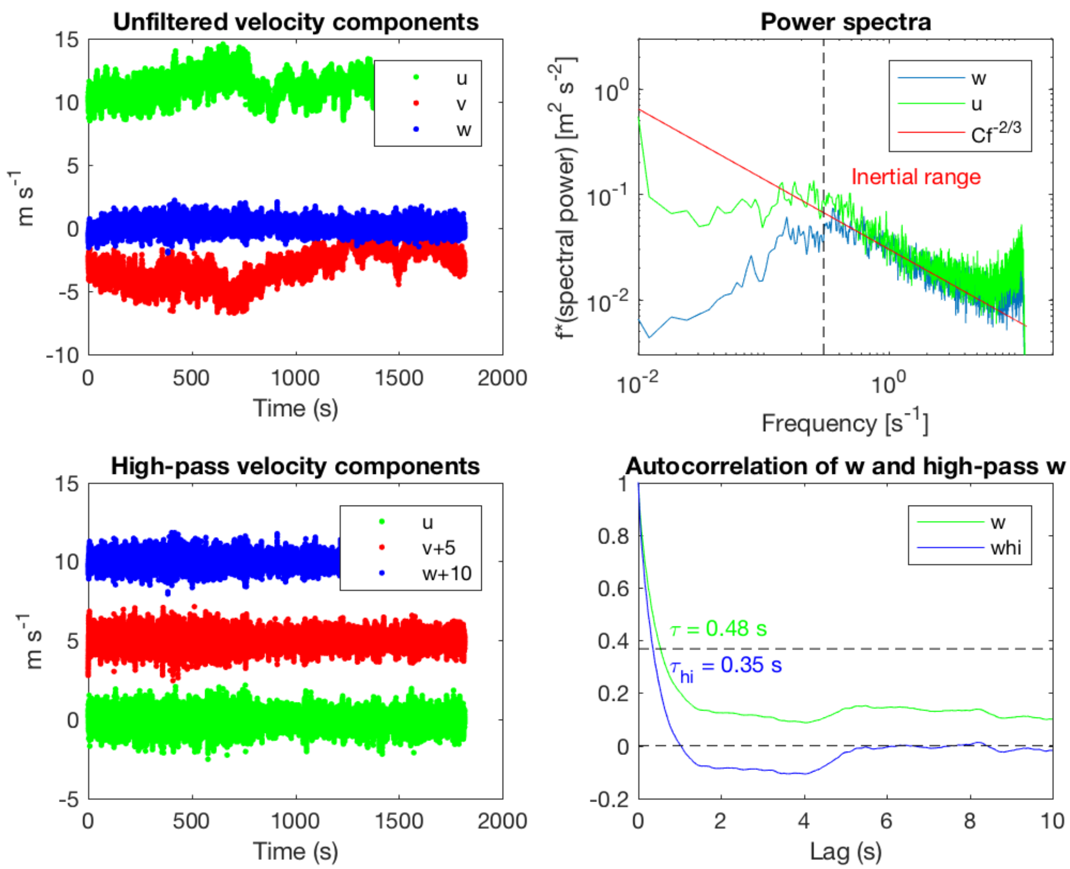

Fig. 1: Statistics of velocity component time series

2. The power spectra of both u and w (upper right panel) show approximate $f^{-5/3}$ behavior from frequencies of 0.3 s^{-1} on up (wavelengths U_0/f of 300 m and smaller), suggesting that this encompasses the inertial range. The red line $Cf^{-2/3}$, $C = 0.03$ m^2 $s^{-8/3}$, is a fit to fP_{ww} for $0.3 < f < 5$ s^{-1}.

3. The TKE dissipation rate is computed from C:

$$C = 0.8\varepsilon^{2/3}\left(\frac{2\pi}{U_0}\right)^{-2/3} \quad \Rightarrow \quad \varepsilon = (1.25C)^{3/2}\frac{2\pi}{U_0} = 4.6\times10^{-4}\ \mathrm{m^2 s^{-3}}$$

4. The filtered velocity components (including w) are shown in the lower left panel. The standard deviation of the filtered w is 0.38 m s^{-1}.

5. We plot the lagged autocorrelations of the raw and high-pass w in the lower right panel. The negative autocorrelations of high-pass w at lags of 1-2 s are due to the alternation of updrafts with downdrafts. For w_{hi} the e-folding autocorrelation timescale is 0.35 s, corresponding to a 35 m characteristic updraft half-width. Since this data is taken in the surface layer, the updraft half-width scales with the measurement height of 30 m. For w this timescale is 0.48 s, which is slightly longer due to retention of the slowly varying low-frequency part of w.

6. I find (fluxes of T and q are given in energy units, momentum fluxes in stress units):

Table 1: **Statistics of high-pass variables**

Variable	u	v	T	q
Hi-pass st. dev.	0.51 m s^{-1}	0.44 m s^{-1}	0.02 K	0.08 g kg^{-1}
Correlation with w	-0.31	-0.04	-0.25	0.39
Vertical flux	-0.07 Pa	-0.01 Pa	-3 W m^{-2}	34 W m^{-2}

The resulting buoyancy flux $B_0 = g(w'T'/T + 0.61w'q') \approx -10^{-5}\ \mathrm{m^2\,s^{-3}}$, which is insignificantly different than zero.