EAS471, Lab 1 "Time Series Analysis" Jan, 2007

Preamble

The accompanying data file 'utah.dat' (6.75 MB) contains a time series of wind and temperature registered at 20 Hz and covering one hour, from two sonic anemometers (1,2) at heights $z_1 = 3$ m and $z_2 = 25.69$ m standing on an isolated tower on a salt flat in Utah (24 May, 2005; the data span local midday). The data are arranged in columns in the order $u_1, v_1, w_1, T_1, u_2, v_2, w_2, T_2$, where u is the northerly component, v the easterly component and w is the vertical velocity. The number of entries (N) in each column should be 20×3600 (but may differ slightly, so either N should be computed from the number of lines of data read, or set slightly smaller than 72,000).

The site was uniform, suggesting micro-meteorological statistics should (also) be horizontally homogeneous[1]. Thus statistics computed from these time series should conform to the established norms for the atmospheric surface layer (eg. see Kaimal and Finnigan, *Atmospheric Boundary Layer Flows*; or Stull, *An Introduction to Boundary Layer Meteorology*; or Garratt, *The Atmospheric Boundary Layer*). In this assignment, you will compute the standard micro-meteorological statistics, the most important being the

[1] The existence of horizontal homogeneity cannot be *proven* on the basis of measurements at a single tower.

friction velocity, whose definition we will take to be

$$u_*^4 = \left(\overline{u'w'}\right)^2 + \left(\overline{v'w'}\right)^2 \quad , \tag{1}$$

and the Obukhov length[2], whose definition is

$$L = -\frac{u_*^3\, T_0}{0.4g\, \overline{w'T'}} \tag{2}$$

where T_0 [K] is bulk air temperature.

Task

Write a program to read the data file, compute, and write to a file the following statistics for each of the two levels:

- mean velocity components U, V, W and mean wind direction $\beta = \arctan(V/U)$
- Reynolds stress tensor $R_{ij} \equiv \overline{u_i' u_j'}$. Expressed as a matrix,

$$\mathbf{R} = \begin{pmatrix} \sigma_u^2 & \overline{u'v'} & \overline{u'w'} \\ \overline{u'v'} & \sigma_v^2 & \overline{v'w'} \\ \overline{u'w'} & \overline{v'w'} & \sigma_w^2 \end{pmatrix}$$

- the correlation tensor $C_{ij} \equiv R_{ij}/\sigma_{(i)}\sigma_{(j)}$
- the kinematic heat flux vector $\overline{u_i' T'}$

[2] L is negative in unstable stratification, and infinite in magnitude in a neutral atmosphere where $\overline{w'T'} = 0$ by definition. It is sometimes called the 'substrate of dynamic turbulence', because in the region $z/|L| \ll 1$ the influence of buoyancy on the turbulence is negligible relative to that of wind shear. Conversely, at $z/|L| \gg 1$ buoyancy is the main generator of turbulent fluctuations.

- the turbulent temperature scale $T_* = -\overline{w' T'}/u_*$
- the Obukhov length
- heat flux density $Q_H = \rho c_p \overline{w'T'}$ (to compute the density, assume the local pressure was $p = 820$ mb).

Using an editor of your choice create a computer program with these functions and/or components:

- self-documentation using comment lines (program name, date, author, function)
- define variables as needed
- declare/set up a subroutine (or function) that will be passed a column (or columns) of data, ie. any one of your many 1-d arrays or 'vectors' $u_1()$ etc. The parameter list for the subroutine will include, at a minimum
  - number of entries in the column, N
  - the name of the array(s), eg. $u, w, ...$
  - the mean, variance, standard deviation (etc.) that it computes

  Note that it is more elegant to use abstract variable names in the subroutine, which every time it is called may take in variables with different names and units etc. from your main program. Your call statement may look something like:

```
call cmputstats(N,u,meanu,varu,sdevu)
```

- main part of program will contain a loop (a DO loop or a WHILE loop) which reads in the data (u, v, w, T, u, v, w, T) line by line
- also populate a real 1d array with N random numbers, which you generate using the command rand() which returns a random number x that is uniformly distributed on the range $0 \le x \le 1$. For example your code might look like this:

```
do i=1,N
  myrandomarray(i)=rand()
end do
```

- Compute the statistics (mean, variance, std. dev) of this bogus data

Document your accomplishment of this task in appropriate detail. Provide graphs of the original time series and interpret your computed statistics in the context of your graphs (eg. indicate the means U etc. and the standard deviations σ_u etc. on your graphs). Comment on the statistics of your random numbers.

The atmospheric surface layer is often called the 'constant flux layer'. Considering the heat and momentum fluxes you have deduced, is the name justified at this site?