EAS 572 Assignment 2 2005

Tables (1, 2) give the mean wind (U) and temperature (T) profiles observed on a tower at Ellerslie, Alberta, in the middle of a flat field of sparse stubble during a fifteen minute period beginning 1345 MDT on June 1, 2001. Windspeed was measured with cup anemometers, which should be assumed to have overestimated the mean speed by 8%. Mean temperature *differences* relative to a reference level ($z = 0.29$ m) were measured by shielded, ventilated thermocouples. One may assume the characteristic uncertainties in windspeed and temperature difference are $\delta_u = 0.05$ m s^{-1} and $\delta_T = 0.1$ ^{o}C.

A wind vane determined that the mean wind direction (expressed in the ordinary compass convention) $\beta_v = 138^o$. A sonic anemometer at $z = 2.2$ m determined the data given in Table (3).

Aim: The mean profiles define the state of the undisturbed ASL. From the given data, estimate for this period: the friction velocity u_*, the temperature scale T_*, the Monin-Obukhov length L, the sensible heat flux density[1] Q_H. Plot the given mean profiles, along with the theoretical profiles implied by your derived u_*, T_*.

From the sonic data compute alternative estimates u_*^s, T_*^s, L^s and mean wind direction $\beta_s = \arctan(V/U)$ (correct for the orientation of the sonic frame, ie. add 90^o). Comment on the measured values of $\sigma_u/u_*, \sigma_v/u_*, \sigma_w/u_*$ in the context of MO similarity theory.

[1]The mean temperature T_0 during this period was about 21^o C, and for the purpose of calculating the density ρ_0 you may assume the atmospheric pressure $p = 93$ kPa.

Profile Fitting Method

Correct the cup anemometers for overspeeding. Create the set of measured differences $\Delta U_z{}^m = U_z - U_{ref}$, $\Delta T_z{}^m = T_z - T_{ref}$ (etc.) where U_{ref} is the windspeed at a reference height, such as $z = 0.65$ m. To each of these differences there correspond (for any guess of the scales u_*, T_*) theoretical differences $\Delta U_z{}^t = (U_z - U_{ref})^t$ (etc.) that may be calculated from the Monin-Obukhov similarity profiles. Your scales should be optimal in the sense that they minimise the dimensionless residual:

$$\begin{aligned} R &= \frac{\sum_1^{N_U} \left(\Delta U^m - \Delta U^t\right)^2}{\delta u^2} \\ &+ \frac{\sum_1^{N_T} \left(\Delta T^m - \Delta T^t\right)^2}{\delta T^2} \end{aligned} \tag{1}$$

Here $\delta u, \delta T$ are estimated instrument inaccuracy. In the present case the number of velocity differences is $N_U = 4$ and $N_T = 2$.

Data

Table 1: Profile of (uncorrected) mean cup windspeed, Ellerslie (AB), 1345-1400 hrs, 1 June, 2001.

z [m]	$U(z)$[m s^{-1}]
6.05	11.53
3.6	10.52
2.12	9.68
1.12	8.28
0.65	7.45

Table 2: Profile of mean temperature difference from reference temperature, Ellerslie (AB), 1345-1400 hrs, 1 June, 2001.

z [m]	$T(z) - T(0.29\text{m})$ [^{o}C]
5.75	-3.09
1.35	-1.52
0.29	0.00

Table 3: Statistics from the sonic anemometer at $z = 2.2$ m over same interval. The sonic was 'facing' east, thus when $v = 0$ wind direction is 90^o. In principle, the statistics should be rotated into a frame for which $W = 0$, but we shall neglect this step.

Property	Value [MKS units]
$\sqrt{\overline{u^2 + v^2}}$	9.17
U	3.06
V	1.88
W	-0.23
T	16.8
$\overline{u'^2}$	2.191
$\overline{v'^2}$	3.357
$\overline{w'^2}$	0.506
$\overline{u'w'}$	-0.225
$\overline{v'w'}$	-0.416
$\overline{w'T'}$	0.287