Chapter 5 : Instrumentation and measurements

5.1 Automatic Weather Station

Automatic Weather Station (AWS) has been designed to replace the conventional climatological station. The AWS is usually battery powered, however it can also be powered from the normal electricity supply with the battery acting as a back up if there is a power failure.

The AWS is connected to the tape recorder in order to transfer all the signals from the input storage into the final storage. The signal can then be read by a computer software system after it has been recorded in a cassette.

The features of the AWS consist of a mast, on which the sensors are supported by a short booms, and a logger box. The logger box is separated from the mast. Experiments have shown that either in the hourly or daily records, the AWS can measure and record meteorological parameters better than that by the conventional station (Rodda, 1976).

The meteorological station of University of Malaya has been provided with AWS which consist of all the instruments needed in automatic weather station measurement. Among the instruments are net radiometer which measures the net radiation, moisture block which measures the soil moisture and pyranometer which measures the incoming radiation. Calibration for some of the instruments is necessary to validate the accuracy of the readings for this area since some of the instruments were designed for temperate region which has a different climate and environment. In this study the calibrations of instruments have been done by the manufacturing company and the values are enclosed with the purchases (see appendix 5)

5.2 Siting Characteristics and scope of research

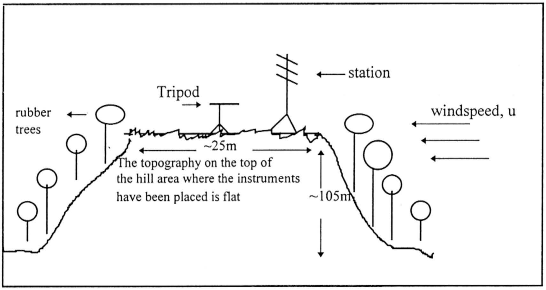

Figure 5.2 (a) : The illustrations of the site of meteorological station, University of Malaya.

The measurements were taken at the meteorological station in the University Malaya, Kuala Lumpur (3°07'N ,100°23'E which is on a hill with an elevation of ~105m. Mature rubber trees were growing around the hill slope. The average height of the trees was 5 m. Friction on the surface of the trees slowed the horizontal wind. This will lead to turbulent flow when it reached the top of the hill. The solar radiation also affected by the slope and by the vegetation cover, this means that the top of the hill will be heated slowly compared to the flat surface at the base of the hill. Atmospheric measurements made at height z over an effective surface z_0 represent fluxes from upwind sources. The EC technique requires that fluxes at z and z_0 be equal.

5.3 Experimental arrangement

Generally, the study site was characterized by a homogeneous distribution of short grass with mean height of 10 cm. The grass area (25m x 20m) was surrounded by rubber trees on a hill slope. The experimental arrangement of the instruments can be seen in appendix 7.

Measurements were recorded using a 21x Campbell Micrologger. The turbulence sensors by EC method consists of a CA27 Sonic Anemometer with a 127Fine Wire Thermocouple and KH20Kripton Hygrometer. These sensors were mounted at about 2.6m height on a rotatable boom attached to a 1m long support arm connected to the mast CM10 tripod. The distance between the two sensors was about 0.12m and the KH20 was set back a few mm to be able to measure the small-scale eddies without risking flow interference or wake effects between the instrument. Parameters measured were vertical windspeed, w', temperature, T' and water vapour,v_q'.

Apart from the fast-response sensors above, measurement of net radiation was also taken using a Campbell Q6-LNet Radiometer. This sensor was positioned at the same level as mentioned above.

Whilst, near surface soil heat flux was estimated by the 107 air temperature probe and the 107B soil temperature probe which was buried about 7 cm underground. The LI200S Pyranometer measured the incoming radiation. Surface wind speed was measured with 03101-5 R.M. Young Wind sentry. The rainfall was taken from the rain gauge.

EC data were taken at a sampling rate of about 10Hz and the sensors were ran at 5 seconds interval, continuously for 24 hours period. The 21x micrologger instruction manual for all the sensors were represented in appendix 6. These data were recorded starting from June 1995 to August 1995. Only several days of observation were chosen to show the results of the influence of the variability of the meteorological parameters on evaporative fluxes. The date an analysis were chosen to study of land surface evaporation and also the boundary layer meteorology(2m above the ground surface) with emphasis on the daily changes of the micro meteorological elements in the energy budget equation.

5.4 Signal analysis software DADiSP (Data Analysis Digital Signal Processing).

The data was analysed using a commercial software DADiSP. The DADiSP or Digital Signal Processing (DSP) is used to manipulate the data because this program has the advantages of handling data in term of signal more efficiently than any other software. The DADiSP worksheet is comprehensive, digital signal processing package which is designed based on the principle of a spreadsheet. This graphics-based worksheet allow us to :

1. Display and manipulate up to 64 wave forms at once.
2. Create a data reduction chain containing up to 64 windows of complex processing step.

Signals of any length can be imported as ASCII or binary files. Once loaded into DADiSP, these signals are stored within a database organized into Labbooks, Datasets and Worksheets.

The DADiSP supplies more than 160 functions for data transformation. These functions can be used separately in window formulae or combined in user-defined expressions called Macros. It provides for the common basic mathematical manipulation e.g. addition, subtraction, multiplication, division and exponentiation to the higher level of calculation like the Fourier Transformation, Spectrum and Power Spectral Density analysis.

Another advantage of this program is that in any worksheet, signals can be zoomed to full screen size, scrolled, expanded, compressed, cursored and edited. Grids' scales can be changed or send to any window out to a printer with or without background signal information.

Other DADiSP worksheet features include :

1. Full support of complex signals or scalars.
2. Symbolic processing of engineering units.
3. Complete Fourier analysis including mixed radix FFT and power spectral density(PSD).
4. User-defined Macro functions.
5. Multi-channel data import.
6. The DSP pipeline to READ and WRITE ASCII or binary files directly from a Worksheet. Pipeline allows external software such as data acquisition, signal filtering or pen-plotting without leaving the Worksheet. The DADiSP provides such a unique approach to the root problem of data analysis, and it has been accepted as a powerful, generic product for data manipulation.

The data which have been recorded in a cassette is read into the computer via the tape recorder and then via the PC 201 software which convert the signal into numbers. The PC 208 will then split the data according to the right parameters. DADiSP can only import these data either in daily or hourly basis due to the lack memory to hold the 24 hours data for every 5 seconds.

The graphs for every parameter were plotted so that the fluctuation of the elements in respond to the changes of the weather can be seen. Parameters plotted were global radiation, net radiation, horizontal wind speed, surface temperature, soil temperature and ground heat flux. The daytime and nighttime regression of the net radiation, horizontal wind speed and ground heat flux with the latent heat flux from EC technique were also presented. Lastly, the measured latent heat fluxes from EC technique were compared with the computed latent heat fluxes from the energy balance equation.

5.5 The calculation of latent heat by the eddy correlation technique.

The conversion of w'Vq' to latent heat flux, LE (Wm^{-2}):

$$LE = Lw'Vq'/(\overline{Vq} * xK_w) \quad \text{----------------} \quad (5.1)$$

where,

L = latent heat of vaporization (2.43×10^6 J/Kg)

$xK_w = 1.436\ cm\ (-0.145\ m^3g^{-1}cm^{-1})$

$= -0.208\ g^{-1}m^3$

$w' = w - \overline{w}$

$Vq' = Vq - \overline{Vq}$

The calculation of sensible heat by the eddy correlation technique

The conversion of w'T' to sensible heat flux, H (Wm^{-2}):

$$H = C_p D_a w'T' \text{ ------------------ } (5.2)$$

where,

C_p = specific heat of air

= 1010 $Jkg^{-1}{}^oC^{-1}$

D_a = air density

= 1.164 k

$T' = T - \overline{T}$

5.6 The calculation of soil heat flux, Q_G using a formulae

Soil heat transfer occurs when there is a flow of heat by conduction between two levels, upper and lower surfaces. This is because there is a temperature difference which by convention is downward for heat flows into the soil .

The calculation of heat flux, Q_G is given by equation below :

$$Q_G = -\lambda(T_2 - T_1) / \delta z \quad \text{or} \quad Q_G = -\lambda dT/dz \text{ ---------------- } (5.3)$$

where,

λ = thermal conductivity (0.25 J/s/m/K)

T_1 = average temperature at the surface (^oC)

T_2 = average temperature at depth, z (^oC)

δz = the soil thickness at depth, z (m)

The equation is for small $(z_2 - z_1)$ and $(\bar{T}_1 - \bar{T}_2)$ and for equilibrium or steady state condition. Thermal constant for λ was taken from Oke (1978).