PROBLEM 1:

Plot the mean daily evolution of horizontal wind magnitude, temperature, CO2 concentration and specific humidity. You can use 30-min averaging windows here.

SOLUTION:
Plotting these variables from the dataset given results in the following figure.

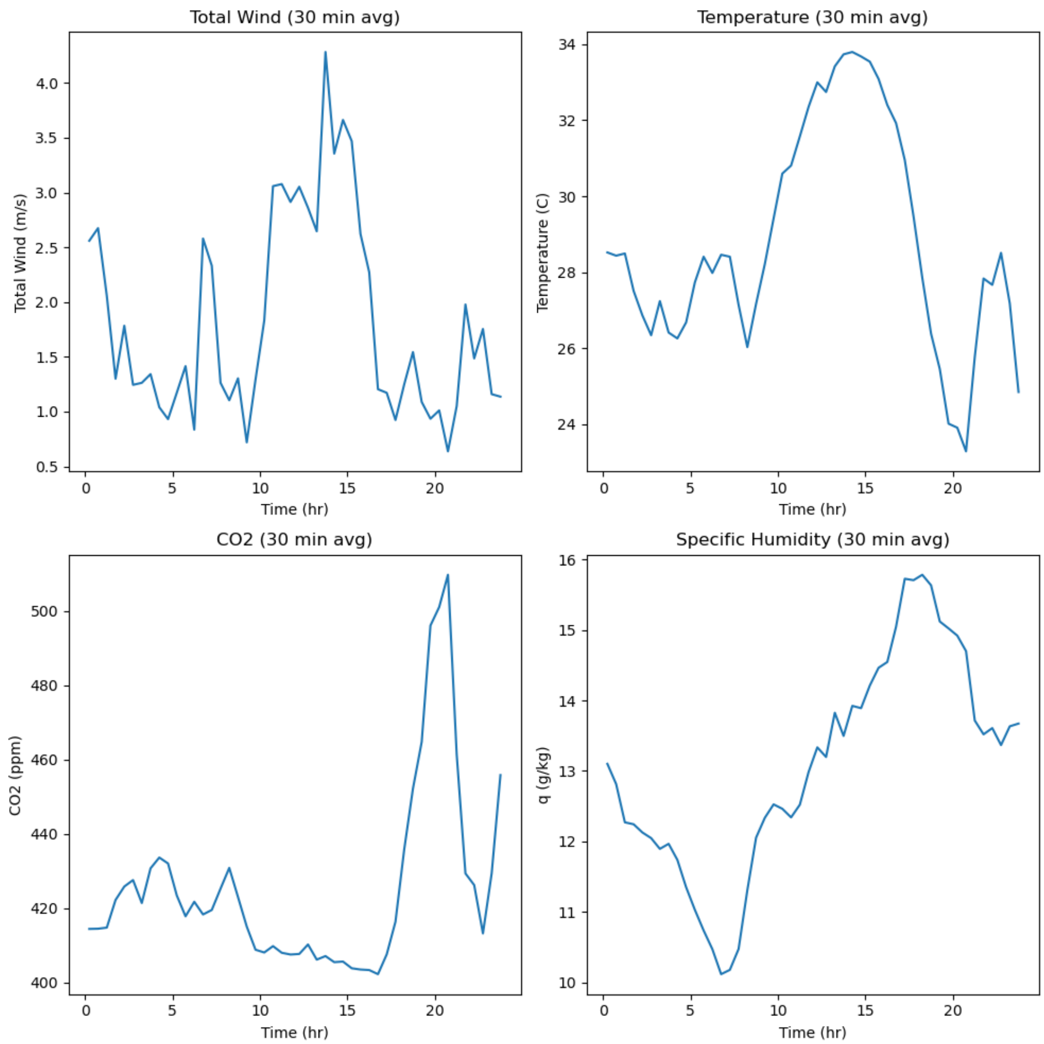

Figure 1: These plots show a relatively standard daytime period between t=9.5 hr and t=18 hr, with a more unique nighttime period with less stable temperatures both in the morning and evening. Normally there would be less wind overnight but in this case there seems to be large scale forcing resuting in less stable wind corrosponding well with the increased periods of overnight temperature.

PROBLEM 2:

Plot the daily evaluations of turbulent kinetic energy and the vertical kinematic fluxes of horizontal momentum (both components), heat, CO2 and moisture. Do that using 5-min and 30-min averaging windows.

SOLUTION:

Again plotting these results in the following figure. As expected, the 30 minute averages have much less variability than the 5 minute averages for all fluxes and turbulent kinetic energy (TKE).

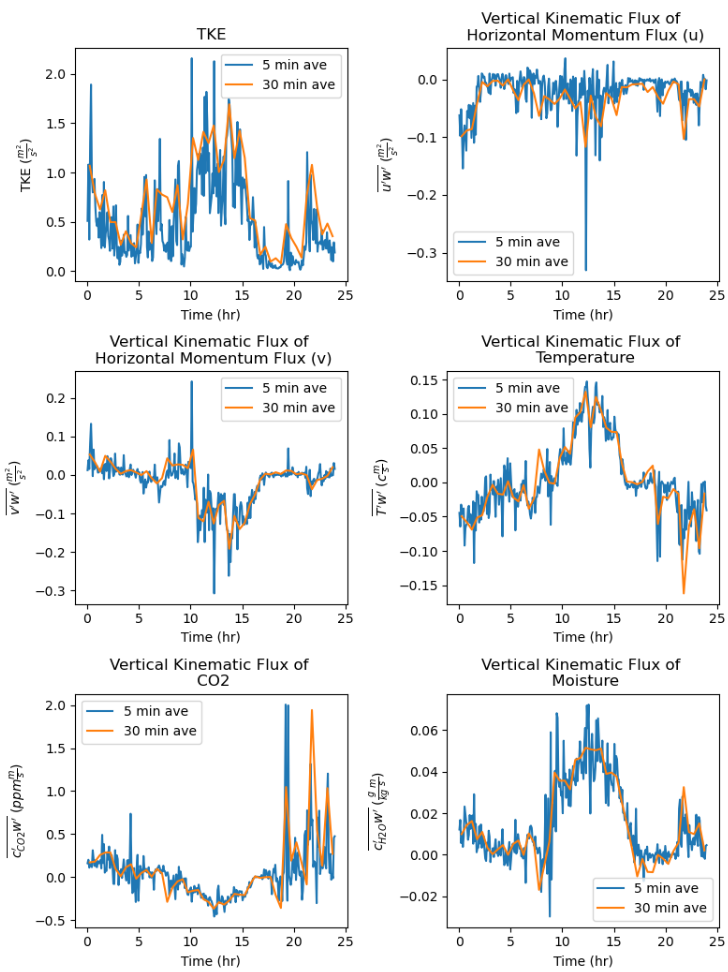

Figure 2: Comparing the 5 minute averages and the 30 minute averages of the turbulent kinetic energy (TKE), vertical fluxes of u, v, temperature, CO2, and q.

PROBLEM 3:

Plot the components of the radiative budget.

SOLUTION:

The radiative budget consists of longwave radiation coming from the atmosphere into the surface (downwelling longwave, L_d), shortwave radiation coming from the sun (downwelling shortwave, S_d), longwave radiation radiating away from the surface (upwelling longwave, L_u), and shortwave radiating radiating away from the surface (upwelling shortwave, S_u). The net radiation is the sum of these terms with the upwelling terms acting as sinks, and the downwelling components acting as sources of net radiative forcing.

$$R_n = L_d + S_d + L_u + S_d \tag{1}$$

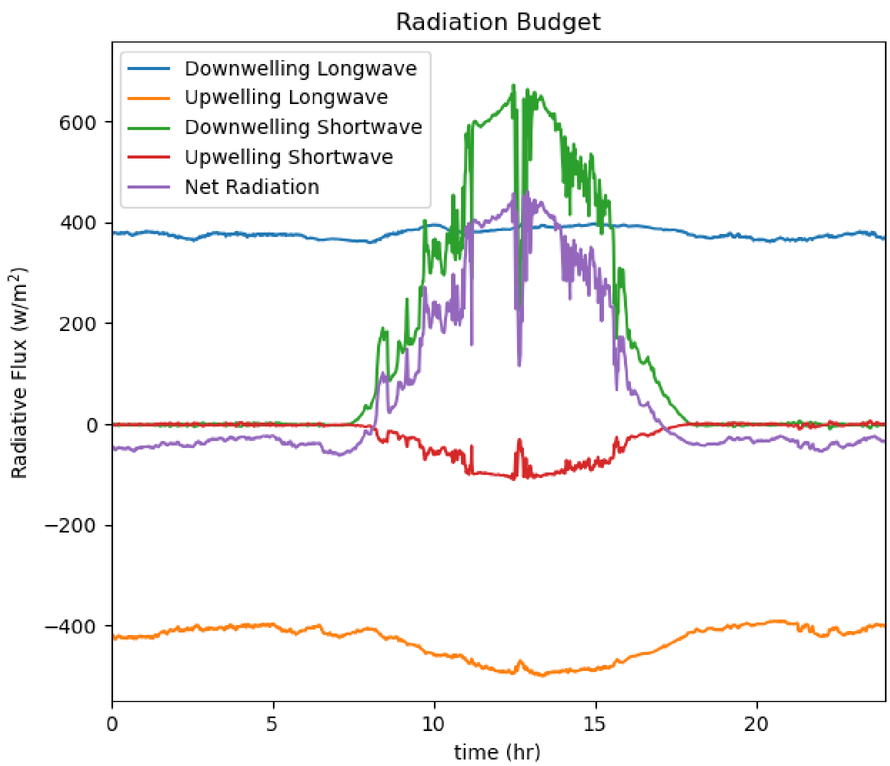

Figure 3: Radiation budget components. Note the drop in downwelling shortwave radiation near t=12 hr, this could be due to clouds or other operational conditions that I am unaware of.

PROBLEM 4:

Plot the components of the surface energy budget for 5-min and 30-min averaging windows in the sensible and latent heat fluxes

SOLUTION:

The components of the surface energy budget are the soil heat flux (G), latent heat flux (LE) and sensible heat flux (H). The net radiation should be the sum of these but is measure separately so we can explore the quality of the closure in problem 5.

$$R_n = G + LE + H \tag{2}$$

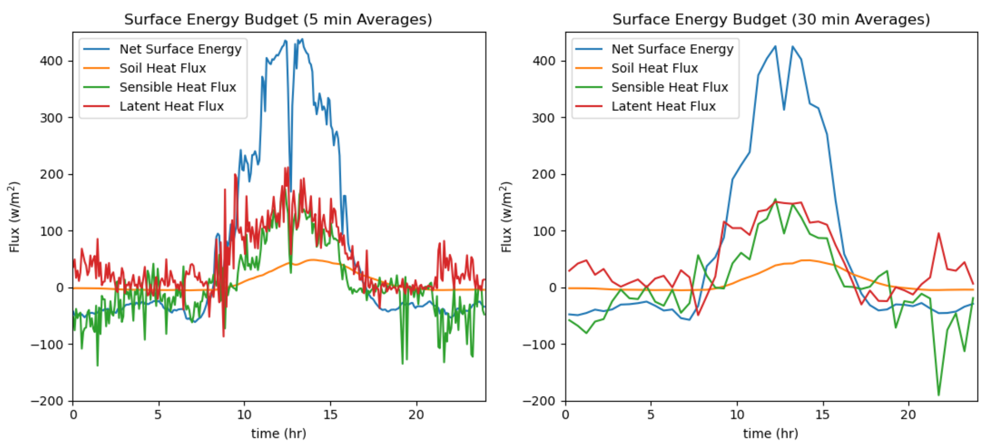

Figure 4: Surface Energy Budget using 5 minute (left plot) and 30 minute averaging (right plot). Again we note the reduction in variance with longer averaging.

PROBLEM 5:

Evaluate the closure of the energy budget separately for day and night periods, and with the 5-min and 30-min averaging windows. Make a critical comparison of the closures found.

SOLUTION:

To determine how good the closure of the energy budget is, I plotted the difference between net radiation and soil flux (R_n - G) against the sum of latent and sensible heat (LE + H). This type of plot allows me to understand which part of the budget equation is dominant. In a perfectly balanced budget equation the data points would all fall on the x=y line, if the turbulent flux dependent terms (H and LE) are are dominant compared to the net and soil term then the points will lie above the x=y line and if the net and soil terms dominate then the points will lie below the x=y line. This method allows me to isolate the terms that depend on turbulent fluxes (H and LE) from those measured more directly (R_n and G)

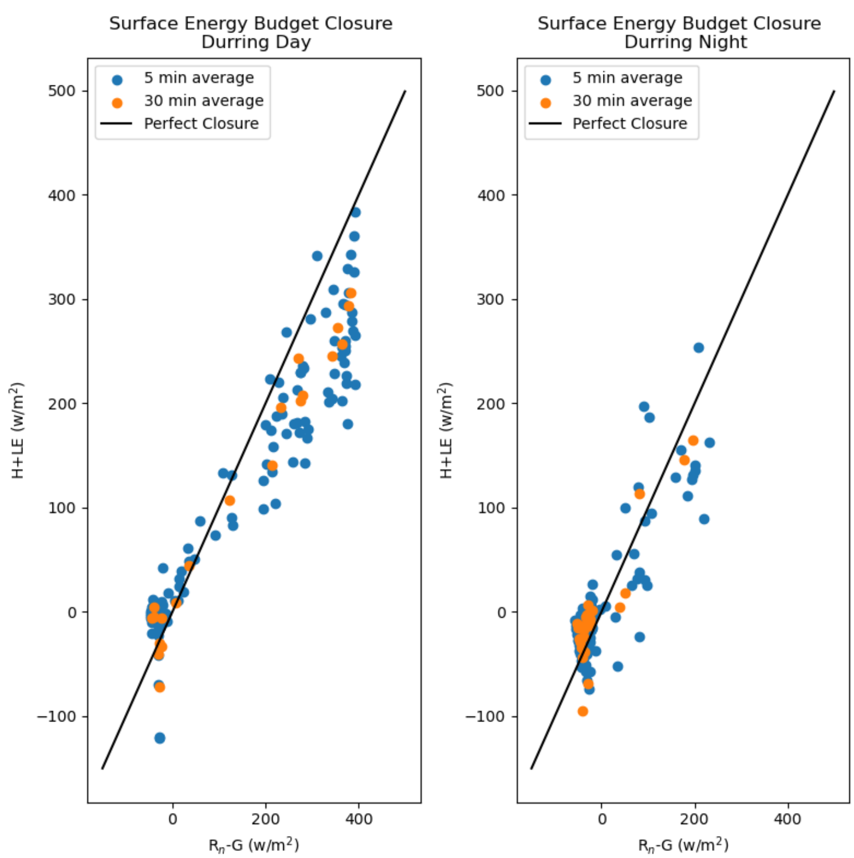

Figure 5: Closure of the energy budget during the day (left) and the closure of the energy budget during the night (right) with 5 minute (blue) and 30 minute (orange) averaging.

Looking at the left panel of figure 5, which shows the closure quality during the day, a trend can be observed where at higher values of $H + LE$ and $R_n + G$ the net and soil terms dominate, while for lower values of $H + LE$ and $R_n + G$ the flux terms dominate. The right panel of figure 5, which shows the closure quality during the night, shows a similar trend for low values of $H + LE$ and $R_n + G$ as seen during the day but for higher values of $H + LE$ and $R_n + G$ there is not a clear trend for one type of term to dominate over the other.

This trend is also captured when plotting the energy budget closure as a function of TKE. To better explore this trend I plotted the residual of the actual and perfect budgets as a function of TKE, shown in figure 6.

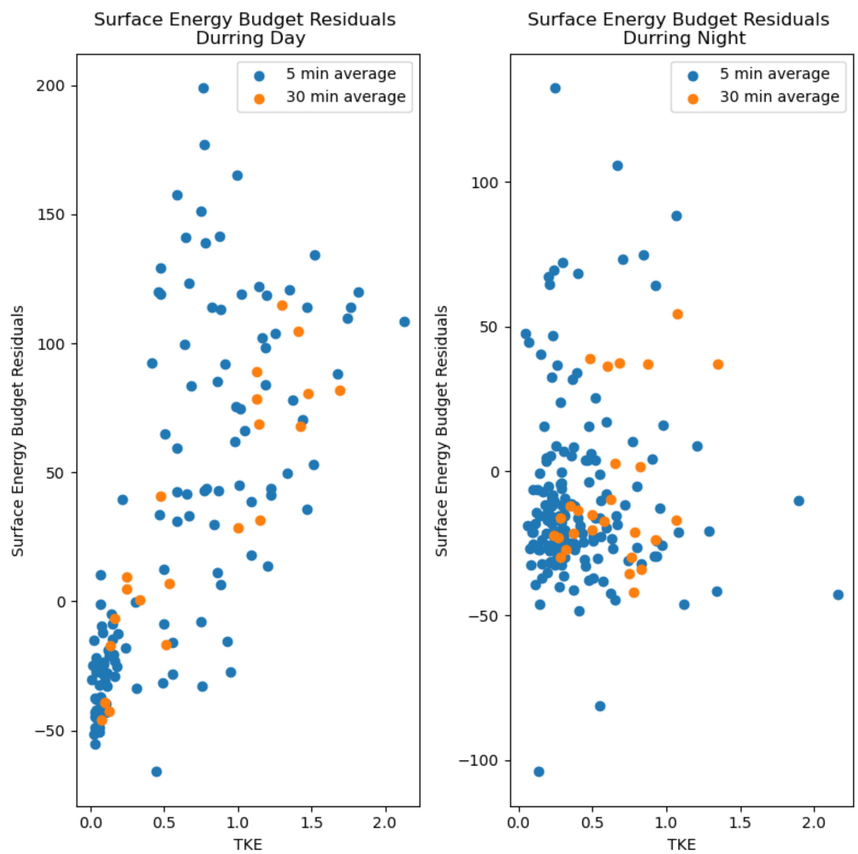

Figure 6: Residuals of the energy budget during the day (left) and the residuals of the energy budget during the night (right) with 5 minute (blue) and 30 minute (orange) averaging.

From this plot it appears that the difference between closure qualitiy at night and during the day is not simply due to a difference in TKE. I don't actually know what causes this difference. Looking at this plot though, I wonder if one could fit a line to the residuals and correct the daytime budget using the linear fit to the residuals.

APPENDIX - Python code

Code Available at:

`https://github.com/Logan-Roy-OK/Obs/blob/master/HW2/HW2_code.ipynb`