UBC ATSC 303 2023W
Lab 12 – Eddy Correlation and Sensible and Latent Turbulent Heat Fluxes (/57)

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Quick resources:

- Turbulence Closure Models: Reynolds Averaged Navier Stokes (RANS) & Large Eddy Simulations (LES) Click here (YouTube link)
- MAQ-22806 Shear, buoyancy and turbulent kinetic energy: Click here (YouTube link)

Learning Goals

By the end of this lab homework, you should be able to:

1. Use observations to calculate turbulence statistics such as mean wind (M), standard deviation (σ), turbulence kinetic energy (TKE), and turbulence intensity (σ /M).
2. Combine fast-response sensor outputs to estimate fluxes using the eddy-correlation method.
3. Use K-theory, Bowen-ratio, and other surface-layer mean profile methods to estimate surface fluxes.
4. Reinforce the learning goals from the lecture and demo.

Part 1 – Eddy correlation methods

Using the high-frequency data provided in the “sonic.xlsx” spreadsheet (sonic.csv also available), answer the following questions.

1. Plot time series of *U*, *V*, *W*, and *T* vs. time. You should make only one plot. Since there does not appear to be a significant slope of the variable during this hour, we do not need to de-trend the data first. Make sure your plots are well labeled. /8

2. Find the mean values of each variable. /2

3. Calculate and plot new time series of the perturbation value of each dependent variable [e.g. $T'(t) = T(t) - \bar{T}$]. /8

4. Find the mean value of each perturbation variable, and discuss their meanings. /4

5. Find the variance of each perturbation variable, and discuss if the turbulence is isotropic or not. /4

6. Find the TKE/m. /2

7. Find the relative turbulence intensities for wind (e.g., for the U component I(U) = std dev.(U')/ abs(average(U)), and say which direction has the greatest relative turbulence intensity. /4

8. Calculate mean values of *u’w’*, *v’w’*, and *w’T’*. Discuss their significance. /4

9. Convert the results from question (8) into stresses (kPa) and sensible heat flux (W/m^2). Assume local air density is 1 kg/m^3, and specific heat for air is C_p = 1004.67 J/(kg K). /3

10. Suppose the Bowen ratio is 0.4. What is the value of latent heat flux? /1

11. Given your answer to question (10), what is the evaporation rate (mm/day) of water from the surface? /1

12. Find the net incoming radiation at the ground needed to maintain a balance of energy at the Earth's surface, assuming that 10% of that net radiative flux is lost by conduction deeper into the ground. /2

Part 2 – Bowen ratio method

The spreadsheet "WhistlerDataAM.xlsx" (WhistlerDataAM.csv also available), contains 30 minutes of data from one of Rosie's Whistler field seasons, extracted from 22 February 2010. Use this data to answer the following:

1. Calculate the average mixing ratio *r* at
   a. 2-m height,
   b. 10-m height.

   You can assume that the pressure data provided is valid at both heights. /4

2. Using the Bowen ratio method, find the sensible and latent heat fluxes (W/m^2) for this half-hour time period. Again, you need to average the data, so you should end up with one value for each (F_H and F_E). State any other assumptions that you make. /6

3. Discuss the significance of the values that you find in question (2), in terms of magnitude and sign. /2

4. Why do you think half an hour of data was used for this method? /2