

Final Project: **Atmospheric Surface Layer Turbulence Analysis – Red Butte Canyon**

Environmental Fluid Dynamics – ME 7710

Group Formation Memo: March 17

Oral Presentations: April 21 & 26 in Class

Final Report: Anytime during Finals week May 2-6

This year's final EFD field experiment will be conducted at the mouth of Red Butte Canyon on the University of Utah campus. We will investigate thermally driven flow and turbulence. Students will be able to enhance the experiments by investigating flow around a manmade windbreak. Each group should obtain the sonic anemometer/thermometer and tethered balloon data set CD. The purpose of this project is to understand the physics of the turbulent flow occurring at the measurement site. You will use both the sonic anemometer data you acquired as well as the tethered balloon data. You will need to come up with a general scientific objective and hypothesis that you intend to test, present on and write-up. For example, a group may choose as an objective: "To better understand the effect atmospheric stability on turbulence for a canyon outflow" and a hypothesis that might be tested could be: "Night-time turbulence is enhanced by the formation of surface level jet."

You must first select a time period for analysis. You may select the entire day for simple statistics and tethered balloon analysis, but you will want to focus on a shorter time period to do your turbulence analysis that is required and outlined below. You may work in groups of 3 or 4. Please select a project topic as soon as possible and get my approval.

Using the Sonic Anemometer data, please perform the following analysis:

1. **Simple Time Averaging:** Calculate (a) 30 minute averages of  $u, v, w$  and  $T$  as well as  $\overline{ws}$ ,  $\overline{wd}$ ,  $\sigma_u$ ,  $\sigma_v$ ,  $\sigma_w$ ,  $u^*$ ,  $H_s$ ,  $tke$ ,  $L$  and  $w^*$  (if appropriate). Be sure to describe the stability during the period being analyzed.
2. **Probability Distributions:** For a representative 30 minute averaging period, generate a CDF and PDF for  $u, v, w$  and  $T$  and report the skewness and kurtosis.
3. Using Taylor's frozen hypothesis, calculate the dissipation rate of turbulent kinetic energy for several 30 minute periods. Calculate the Kolmogorov length scale.
4. Calculate the autocorrelation of at least one 30 minute period. What does this indicate?
5. **Turbulent Spectra:** For at least one 30 minute averaging period calculate the following turbulent energy spectra:  $S_{uu}$ ,  $S_{vv}$ ,  $S_{ww}$ ,  $S_{TT}$  as well as the following cospectra:  $S_{uw}$ ,  $S_{vw}$ ,  $S_{wt}$ . What do these spectra indicate about the boundary layer being analyzed? Is there an inertial subrange?

NOTE: Please do NOT use Matlab's built in functions for this project (Except for FFT). It is important that you understand how each of these calculations is made.

Prepare a well-written and well-organized report detailing all of your calculations and significant findings. It should be in a "journal" style, do not hand in a pile of Matlab codes and plots. The report should be no more than 15 single spaced pages. In addition, be prepared for an oral presentation of your results. Be sure to fully describe the physical

meaning of these data that you have processed. Oral Presentations should be 15 minutes in length.

The following equipment will may be utilized during this project:

*Atmospheric Research Inc., TSB-9, Portable Tethered Meteorological Tower* - 9 m<sup>3</sup> helium filled balloon that can be used for vertical profiling of various atmospheric variables using tethersondes up to approximately 1500 m.

*Vaisala Tethersondes*: Measurements of wind speed and direction, temperature, pressure and relative humidity are made using tethersondes. Each sonde transmits a signal in the 395-410 MHz frequency range to a receiver that communicates with a laptop computer via a serial connection. Each system is capable of accommodating up to 6 tethersondes. For this project you may utilize either one sonic in a profiling mode or 2 sonics in a “tower mode”.

*Campbell Scientific Sonic Anemometers*: 3-D sonic anemometers (Campbell Scientific model CSAT3) are used to obtain tower based velocity and sonic temperature measurements in conjunction with standard eddy flux measurements. Each of the sonics can be fitted with fine-wire thermocouples. The spatial resolution of the sonic anemometers is ~10 cm. Time series data from the sonic anemometers are typically sampled at 10 Hz or more. For this project, you will use 4-sonic anemometers.

*Campbell Scientific CR5000 Data Loggers*: The CR5000s are environmentally rugged, stand-alone data loggers with 20 differential analog input channels. Time series data, typically sampled at 10 Hz, are stored on a PC card and downloaded daily to a separate laptop. Two of these data loggers are available for the experiment.

*TSI Incorporated Model 8520 DustTrak Aerosol Monitors* – This battery run device uses an optical method to can measures particle concentrations (mass density) of either PM1, PM2.5 or PM10. The instrument measures 90° light scattering at a wavelength of 780 nm (near-infrared) and the mass density measurement is achieved through a calibration with ISO 12103-1, A1 test dust<sup>1</sup>. The different size ranges are achieved by using different inlets. The instrument can sample at rates up to 1 Hz. Two DustTrak’s will be available for measurements in or field experiment.

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<sup>1</sup> Moosmüller, H, W Arnott, C Rogers, J Bowen, J Gillies, W Pierson, J Collins, T Durbin, and J Norbeck, *Environ. Sci. Technol.* 2001, 35, 781-787