WIND MEASUREMENT LABORATORY

1. Objectives

The objectives of this lab are to familiarize you with anemometers (wind sensors), to calibrate a weather station Davis wind sensor against a NIST-traceable standard, and to determine the time constant of a two wind sensors. We will use the 3×3 wind tunnel behind Guggenheim Hall.

2. Tasks

2.1. Calibrate the Davis and then the Gill anemometers (one at a time) against the NIST traceable cup anemometer (a cup anemometer made by RM Young) in the wind tunnel. The Young anemometer gives a voltage V_{Young} proportional to wind speed, and the NIST-certified calibration is

$$U_{\text{NIST}} = c\, V_{\text{Young}} + d$$

where $c = 12.12 \pm 0.08$ m s^{-1}V^{-1}, $d = 0.08 \pm 0.05$ m s^{-1}, and U_{NIST} is the NIST wind speed in m s^{-1}.

The wind tunnel should be used to generate roughly 5 different steady wind speeds (e.g., 4, 8, 12, 16, 20 m s^{-1}) for your calibration of the Davis and Gill anemometers. Approximately 1 minute of data collected at each wind speed should be sufficient. Work up in wind speeds because the braking system on the 3×3 is unable to effectively decrease wind speeds. Once this has been done, switch off the tunnel and continue to log data as the wind speed in the tunnel gradually falls. Check for any sticking of the Davis sensor at low wind speeds. The three anemometer readings are captured to a data-logger, which is time-stamped. Remember to make a note of the times that you carried out the various parts as this will aid in your analysis later.

2.2. When the wind speed is below 2-4 m s^{-1} you can examine the time response of the Young sensor (the Davis is not good for this because it records the number of complete turns rather than a voltage as the other sensors do). Determine the time constant (response time) of the Gill and Young anemometers, i.e. the time for the difference between actual and measured wind speed to fall to 1/*e* of the initial difference. Do this for three different wind speeds as the wind drops following a shut down of the tunnel motor. This can be done by blocking the rotation of the Young cups or Gill propeller until the tunnel wind speed has equilibrated and then releasing the anemometer. The blocking should be done with a rod through the bottom of the tunnel (to be demonstrated). After release, the anemometer output should asymptotically approach the tunnel windspeed. As this is changing with time, one of the tricks of the analysis will be to fit a curve to the tunnel wind speed so that you can determine your “actual” wind speed. For time response, you should use a methodology similar to that for the temperature time response in Lab 1.

3. Questions to answer

3.1 What is the bias of the Davis anemometer relative to the Young anemometer. Consider slope (gain) and offset biases. A gain bias would result if the slope is different from unity; a zero bias results if the intercept is non-zero. Use linear regression of the form $U_{\mathrm{YOUNG}} = (a \pm s_{a)}\, U_{\mathrm{DAVIS}} + (b \pm s_b))$ to determine the slope a (and its error) and the offset b (and its error).

Use graphs to show the relationships where appropriate.

3.2 The Young cup anemometer against which you have calibrated the Davis is a "transfer" standard. Taking into account the uncertainty on the Young relative to the NIST true wind value, **determine the total uncertainty on the Davis and the Gill wind measurement**. (This is analogous to the total uncertainty on the temperature measurement in the temperature lab). Use the linear relationship for U_{YOUNG} in 3.1 to calculate the variance on the Young-Davis measurement (S_{Y}^2) from the general "combination of errors" method (see the Temperature Lab). Then also use the linear relationship for the NIST wind ($U_{\mathrm{NIST}} = (c \pm s_{c)} \mathrm{V}_{\mathrm{YOUNG}} + (d \pm s_d))$ to get the variance on the NIST wind (S_{N}^2) from the "combination of errors" method. Calculate a total variance, which is the sum $S_{\mathrm{Y}}^2 + S_{\mathrm{N}}^2$.

3.3 Determine the **time constant** for the Young and Gill anemometers for different wind speeds from linear regression by first taking logs. Be sure to include the uncertainty on the time constant. The error will allow you to assess the significance of different response times. Rationalize any differences for the different anemometer response times. Estimate the anemometer **distance constant** and its uncertainty at the different wind speeds. How does the time constant change with wind speed?

To turn your data into a linear expression, you should use the following

$$U = U_{\mathrm{tunnel}} \left(1 - e^{-t/\tau}\right)$$

Where U is the measured wind speed, as the anemometer spins up from zero, for the particular sensor (convert using your calibration), U_{tunnel} is the wind speed in the tunnel, t is the time since the stick was removed, and τ is the time constant. Rearranging this expression and taking logs you get

$$\ln(1 - U/U_{\mathrm{tunnel}}) = -\, t/\tau$$

A plot of $\ln(1 - U/U_{\mathrm{tunnel}})$ vs t should therefore be close to linear, with a slope that is $-1/\tau$. You should use linear regression to find this slope and determine τ. Determine the tunnel wind speed using the data when the anemometer has more or less reached equilibrium. Doing this for 3 or 4 tunnel wind speeds will allow you to see how the time constant varies with wind speed and determine how constant the distance constant is.

Appendix: Data format

The data exported from Labview is easily ingested into Excel using the *Import Data* feature. Following the header information, the data columns are:

```
X_Value/Untitled/X_Value/Untitled 1/X_Value/Untitled 2/X_Value/Untitled 3/X_Value/Untitled 4/X_Value/Untitled 5/X_Value/Untitled 6/Comment
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Where Untitled, Untitled 1 and Untitled 2 are the time (Year, Day of Year, Minutes after midnight), and Untitled 4, 5, 6 are the data from the three anemometers. Part of your job is to figure out which is which.

For Matlab users, there are a number of tools to import text files:

http://www.mathworks.com/access/helpdesk/help/techdoc/index.html?/access/helpdesk/help/techdoc/data_analysis/f4-8947.html