

MAE 126A Winter Quarter 2013

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Environmental and Mechanical Engineering Laboratory

Atmospheric Turbulence Measurement

General description

In this experiment, you will measure atmospheric turbulence, using Campbell Scientific sonic anemometer-thermometers (CSAT), at two different heights and net radiation, using a NR-LITE net radiometer (Fig. 1).

CSAT measures the wind speed using the Doppler shift effect. Each axes of CSAT pulses two ultrasonic signals in opposite directions to measure the wind speed (U , V , W for x, y and z- component, Fig. 3) from the time of flight. Temperature (T_s) is also estimated by measuring speed of sound. Since, speed of sound depends on air pressure, density and moisture content, temperature measured by the CSAT is not the actual air temperature. For more details please refer to the Appendix A.

The NR-LITE net radiometer measures the net radiation (R_{net}) by performing an algebraic sum of upwelling and downwelling shortwave and longwave radiation. Positive values correspond to net incoming radiation (heating of the ground). For more details please refer to the Appendix B.

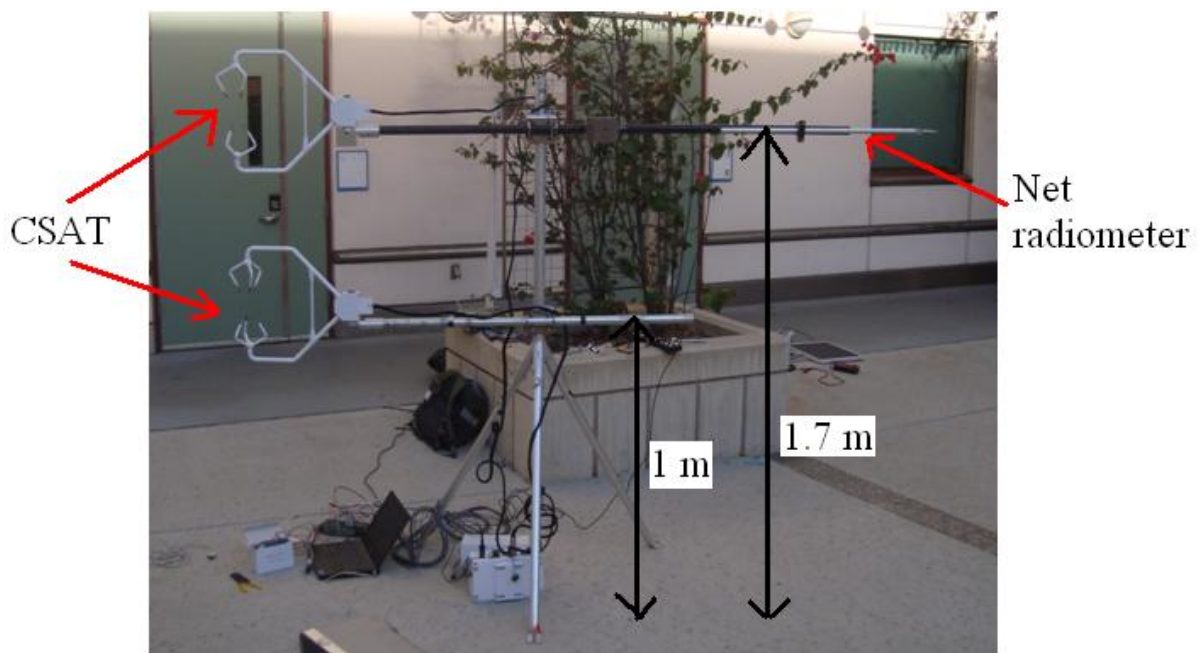


Figure 1. Set-up for atmospheric turbulence measurement experiment.

Objective

The main objectives of this experiment are to master:

1. Installation and data logging of atmospheric sensors, (Week 1)
2. Data analysis with MATLAB, (Week 1-3)
3. Atmospheric turbulence. (Week 2-3)

Procedures

Week 1: Installation and data logging of atmospheric sensors

1. Mounting of CSAT

a) The CSAT consists of different parts (Fig. 2): i) anemometer head, ii) anemometer mount, iii) SDM and power wires, and iv) CSAT electronic box.

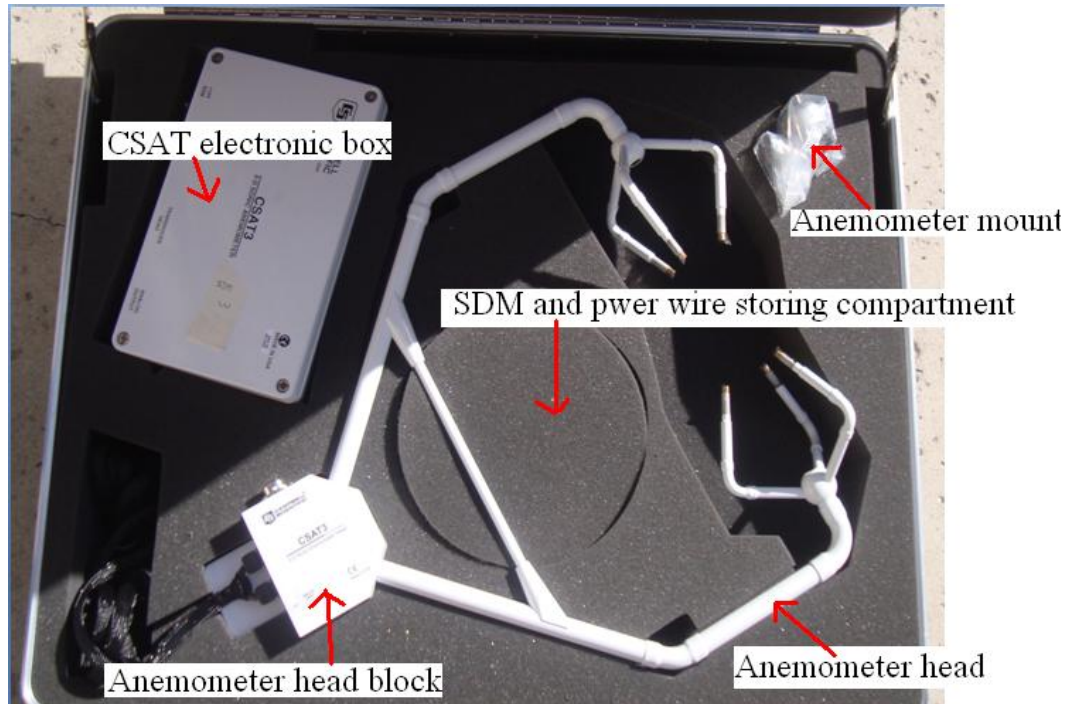


Figure 2. Different parts of CSAT.

b) Locate the serial number written on the CSAT anemometer head and CSAT electronic box. **Do NOT mismatch these two, otherwise calibration will be off.**

c) Note the SDM address (written on the CSAT electronic box).

d) Mount the anemometer mounts on the two long horizontal arms of the tripod, on the same side.

e) Mount the anemometer head on the anemometer mounts carefully. **Always hold the anemometer head by its block, where upper and lower arms meet. Never touch the sensor tips.** Level the anemometer head using the bubble level indicator located on the upside of the anemometer. Point the horizontal arm into the prevailing wind.

f) Please mount the CSAT with SDM address 3 in the lower position (about 1 m) and that with SDM address 4 in the upper position (about 1.7 m).

g) Connect the wire from anemometer head to the “Transducer head” port of the electronic box.

h) Connect the SDM and power wires to the “+12V SDM” port of the electronic box.

i) Determine the CSAT orientation using a compass.

j) Note down the CSAT axes (Fig 3).

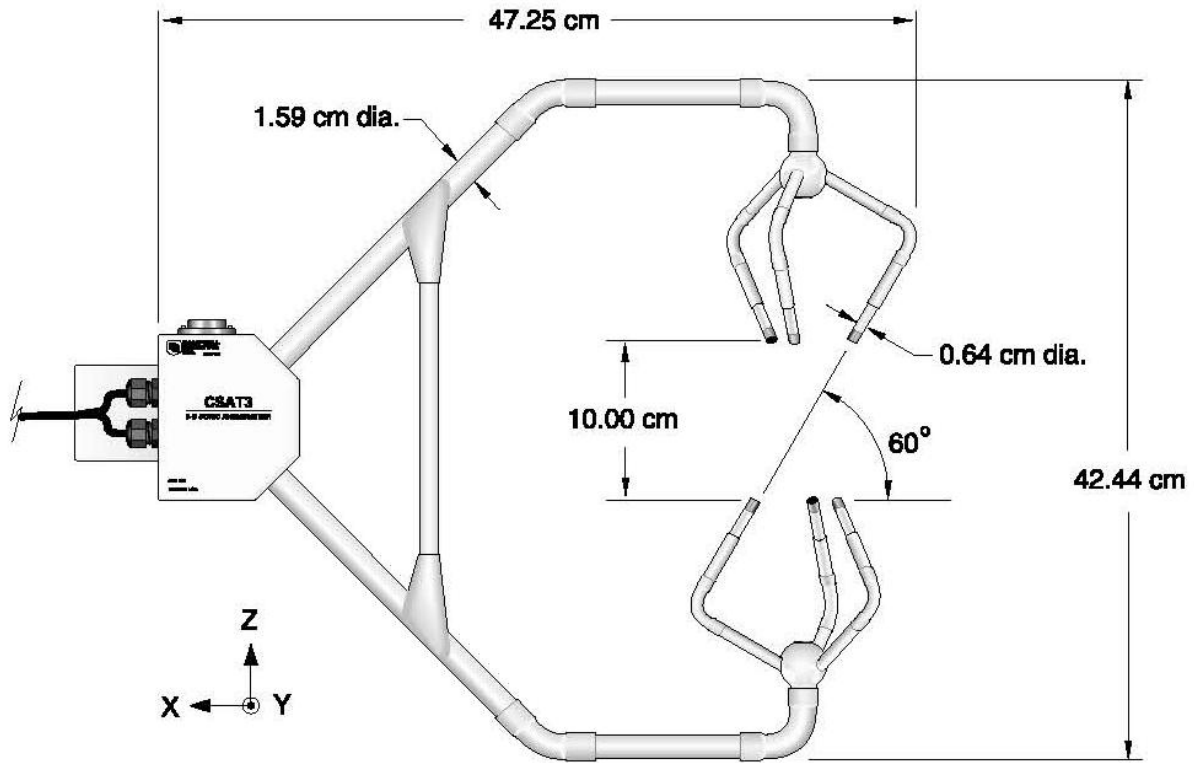


Figure 3. Dimensions of CSAT head. (Taken from CSAT manual)

2. *Mounting of Net radiometer*

a) Locate the net radiometer sensor. **Always hold the sensor by the support arm and never touch the head of it.**

b) Note down the serial number of the sensor. Each sensor is associated with unique calibration factor (current sensor has calibration factor of $14.1 \mu\text{V W}^{-1} \text{m}^{-2}$).

c) Mount the net radiometer on the upper horizontal arm of the tripod on the opposite of the CSAT.

d) Level the net radiometer using the bubble level indicator, located on the upper side.

3. *Familiarization with CR1000 datalogger*

a) Locate the SDM ports and differential ports on the datalogger (Fig 4).



Figure 4. Differential (for net radiometer) and SDM ports (for CSAT) of the CR1000 datalogger.

b) Connect the SDM and power wires to the SDM ports following the wiring instruction for CSAT (Table 1).

Table 1. Wiring instructions for CSAT

Wire color	Ports	Wire note
Green	SDM-C1	Data
White	SDM-C2	Clock
Brown	SDM-C3	Enable
Black	G	Reference
Clear	G	Shield
Red	12 V	Power
Black	G	Power reference

c) Connect the wires from net radiometer to the differential ports following the wiring instruction for net radiometer (Table 2).

Table 2. Wiring Instruction for net radiometer

Wire color	Ports
White	1H
Green	1L
Clear	G

d) Connect the datalogger with the battery.

4. *Start data collection*

- a) Login to the student account of the DELL laptop and start Loggernet from the desktop.
- b) Connect the datalogger with the laptop using the RS-232 and USB connection wire. Connect the RS-232 port side with the datalogger and USB side with the USB located at **the top upper right hand corner of the laptop**.
- c) In the Loggernet program, go to Main, and then go to Connect.
- d) Highlight the CR1000_mae126a in the Stations Menu and click connect.
- e) After successful connection, set the clock of the datalogger by clicking set button in the clocks block.

f) Send the datalogger program mae126a.CR1 by clicking the “Send” button in the program block. The file is stored in the desktop of the laptop. **Note:** When you send the file to the datalogger, old data stored in datalogger will be lost.

g) Check your data by selecting Table 1 in the Table Monitor: Passive Monitoring block. In the table RecNum, TimeStamp, BattV, NR_Wm2, Ux1, Uy1, Uz1, Ts1, Ux2, Uy2, Uz2, Ts2 are the sample number, time stamp, battery voltage, net radiation, U , V , W , and T_s from the lower CSAT and U , V , W , and T_s from the upper CSAT. Click the start button in the same block. It will update the reading every second. **Note:** The datalogger is sampling at a frequency of 10 Hz, but the table monitor is reporting the data using 1 Hz.

5. *Tasks*

a) Observe air flow in the EBU II quad (inside the courtyard and the breezeway) and speculate why the air is not still.

b) Blow some air to the CSATs, and note how the readings are changing.

c) Cover the upper side of the net radiometer with your hand and note how the readings are changing and why.

c) Cover the lower side of the net radiometer with your hand and note how the readings are changing and why.

6. After finishing up the measurement, dismount all the sensors carefully. Please check the voltage of the battery using a multimeter, and the remaining battery charge of the laptop and let your TA know.

7. *Downloading data*

a) If datalogger is not connected (for Week 2 and Week 3) with the laptop, reconnect the datalogger by following Week 1, Part 4, up to step c; otherwise omit this step.

b) Click collect now in the menu.

c) After successfully downloading the data, Loggernet will display where your data is stored. Copy your data from the laboratory laptop to your USB.

8. *MATLAB tasks*

a) Familiarize the MATLAB. It has great help in the MATHWORKS website (<http://www.mathworks.com/help/matlab/index.html>).

b) Use read_file.m script to read your data.

c) Familiarize yourself with time vector. (Hint: datenum converts a Julian date to the time vector, datestr does the opposite, datevec generates a matrix of Julian dates from datenum)

Week 2: Measure atmospheric turbulence

1. *Measurement location*

a) Go to Warren Court and find an open location for your measurement, not disturbed by traffic. Generally, the east side of the first grass area is ideal. The CSATS should be setup facing the library. Note down the location of your measurement site using GPS in your mobile phone or Google Map.

2. *Setup the instruments*

- a) Follow Week 1 procedure from part 1 to 4. If you are stuck with something please ask your TA. Note that the datalogger is starting to collect data immediately after you uploaded the datalogger program. Note the exact time when you have vacated the setup area such that the measurements are undisturbed.
- b) It is a good practise to disconnect your laptop from datalogger, after making sure the former is collecting data correctly. This will preserve the battery of the laptop. To disconnect the datalogger from laptop, just either remove the RS-232 port from the datalogger or remove the USB port from laptop. This action will not terminate data collection, as long as the datalogger remains connected to the battery. Let the laptop go to the sleep mode.
- c) Collect data for 20 min. With 10 Hz frequency, this will give you 12,000 samples. Do not leave the equipment unattended.
3. After finishing up the measurement, dismount all the sensors carefully. Please check the voltage of the battery by multimeter, and the remaining battery charge of the laptop and let your TA know.
4. *Download data*
- a) Follow the procedure of Week 1, part 7.
5. *MATLAB tasks*
- a) Read the data file into MATLAB.
- b) Write MATLAB scripts to perform following tasks:
- i) Plot the entire time series of U , V , W , T , $Rnet$ using five subplots. Comment: What are the trends of each variable and why? Why is this a turbulent flow?
- ii) Compute mean \overline{Rnet} , \overline{U} , \overline{V} , \overline{W} and plot the fluctuations u' , v' , w' , T' . Comment. Why is \overline{W} not expected to be zero for this particular setup? What fluxes of radiation impact $Rnet$? Obtain the downwelling solar radiation from <http://solar.ucsd.edu/lave>. Roughly estimate the magnitude of the other fluxes that contribute to $Rnet$.
- iii) Plot the time series of $u'w'$ and $w'T'$. Compute the covariance (cov, in MATLAB) and correlation coefficients (corrcoeff in MATLAB, r) between U & W and W & T . [Note that cov and corrcoef in MATLAB outputs a 2x2 matrix. The diagonal elements are the “covariances” of a variable against itself (i.e. the variance) while the off-diagonal elements are the covariances. Likewise for corrcoef.]
- iv) What can you infer from the sign and the value of $r(T,W)$? What is the physical meaning of $cov(T,W)$? Discuss the relationship between the time series plot of w' , T' and $cov(W, T)$? Discuss the sign of $r(U,W)$.
- v) Assuming neutral atmospheric conditions compute the velocity profile in the log layer of the atmosphere using measurements from one CSAT (Note: In the equation input $\sqrt{\overline{U}^2 + \overline{V}^2}$) for \overline{U}). Compare the mean velocity estimated for the height of the other CSAT with the actual measurements.
- vi) Compute all possible terms of the surface energy balance. Estimate the magnitude of the remaining terms and interpret the associated physical processes.

Week 3: Measure atmospheric turbulence

Bring your laptop to present your MATLAB analysis to the TA and get assistance.

Appendix A. Theory of CSAT operation

Refer to the APPENDIX C from CSAT manual, which can be obtained from the following website (<http://s.campbellsci.com/documents/us/manuals/csats3.pdf>).

Appendix B. Theory of Net radiometer operation

Refer to the section 1 from net radiometer manual, which can be downloaded from the following website (<http://s.campbellsci.com/documents/us/manuals/nr-lite.pdf>).