

Lab Assignment 5. Radiation

Objective: (1) Become familiar with instrumentation to measure solar, infrared, and net radiation. (2) Be able to diagnose individual terms of the radiation budget.

Before the Lab Session. YOU MUST HAVE YOUR ANSWERS TO QUESTIONS 1-8 REVIEWED AT THE BEGINNING OF THE LAB OR YOU WILL NOT BE ALLOWED TO START!!!

- Read through Chapter 10 on measuring solar radiation.
- Look around outside for at least three relatively level locations with varying surface conditions (grass, pavement, snow, etc.)
- We will be evaluating the radiation terms from the standpoint of the earth’s surface, i.e., “+” means energy gain by the earth’s surface and “-” means energy loss by the surface:
- Global Solar Radiation ($K\downarrow$) = Direct Solar ($S\downarrow$) + Diffuse Solar ($D\downarrow$)
- Net Radiation (Q^*) = Net Shortwave (K^*) + Net Longwave (L^*)
 = Global Solar Radiation ($K\downarrow$) – Shortwave Reflected ($K\uparrow$)
 + Longwave Incoming ($L\downarrow$) – Longwave Outgoing ($L\uparrow$)
 = $(1 - \text{Albedo } (\alpha)) * \text{Global Solar Radiation } (K\downarrow) + \text{Net Longwave } (L^*)$
- *Question 1.* Draw a couple simple diagrams illustrating these terms
- From (http://mesowest.utah.edu/cgi-bin/droman/meso_base.cgi?stn=WBB&unit=1) use the metadata and information for the WBB station to complete the following using the Apogee clear sky calculator <http://clearskycalculator.com/pyranometer.htm>. Look down the page to see the intermediate calculations
- *Question 2.* Complete the following information

Latitude	Longitude	TZ longitude	Elevation	Julian Day of year (Feb 22) 3 PM	Time of solar noon/solar zenith angle	Top of atmosphere short wave(W/m2)	Assume T=5C RH=20% Model estimated SW (W/m2)	Assume T=10C RH=50% Model estimated SW (W/m2)

- *Question 3.* Read through the information on the sources of errors associated with the Apogee clear-sky calculator (http://clearskycalculator.com/model_accuracy.htm). Describe in a paragraph why the calculation is most sensitive to pollution; temperature; and relative humidity when used during the middle of the summer at solar noon. Comment briefly about some of the issues associated with estimating clear-sky shortwave radiation in mid-February at 3 PM.
- *Question 4.* Using the Stefan-Boltzmann relationship $E = \sigma T^4$ and $\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2\text{K}^4)$, estimate the infrared radiation (W/m^2) from the surface (where T is in Kelvin). Assume the emissivity of snow (dead grass) is 0.98 (0.93). Show your calculations.

Surface	T=-5C	T=0C	T=5C
Black body			
Snow			
Dead grass			

- *Question 5.* Refer to the information on the Eppley spectral pyranometer here: <http://www.eppleylab.com/PrdPrecSpectralPyrntr.htm>. Discuss in a single paragraph the operating principle and key characteristics of the sensor.

- *Question 6.* Compare the characteristics and operating principle of the Eppley infrared radiometer from the information available here: <http://www.eppleylab.com/PrdPreclnfRadmtr.htm>
- Read the manual on the CNR2 net radiometer: <http://www.campbellsci.com/documents/manuals/cnr2.pdf>
- *Question 7.* Describe briefly how the net radiation is calculated from the CNR2. What do you need to know in order to convert the output voltages from the two pairs of sensors to net short-wave and long-wave radiation values?
- Everyone in the lab session will work together to collect the necessary data. You will have two laptops connected to two CR1000s: (1) one connected to a CNR2 sensor and (2) one connected to the Eppley PIR and the two PSP sensors. Be sure you have all of the data collected before leaving the lab session.
- *Question 8.* Familiarize yourself with the program 'rad.cr1' available from the class web page. List the parameters you will collect as part of this lab.

Parameter							
What it refers to							

1. Checking the Equipment in the Lab

- Reboot the laptops. Create folders on the netbooks using your team number (M or T) and lab number, e.g., M_5 or T_5
- Copy the rad.cr1 from the class web page into the folders on the laptops.
- Check the wiring listed in the program to what is connected to the CR1000's
- Check battery voltages. Use Loggernet to connect to the CR1000s and send the programs.
- Click on the Custom download option. Change the Collect Mode to "Specific Records"
- Select Change File Name and create a file in your folders that will contain the last 200 records
- Use the keypads to monitor the data
- You should now be able to go and open your file with Wordpad or Notepad. Do so.
- Once you are sure everything is working with ALL equipment, go outside and set up the equipment. Don't forget to take two IR guns.

2. Collecting Data Outdoors:

Measuring the individual terms of the radiation balance over three different surfaces.

- Make sure all sensors are level over the same surface type (pavement, grass, snow, etc.) with the PIR and PSP sensors facing upwards. Shade one of the PSPs to block the Direct Solar Radiation (S_{\downarrow}), recording only the Diffuse Solar Radiation (D_{\downarrow}).
- Collect data for 10 minutes. Record the start and end times. Record the surface temperature with the IR gun every minute. If low-mid clouds are present, record the cloud/sky temperature every minute as well.
- Let the CNR2 continue to collect data but flip the PIR and PSP sensors over facing down. Collect data for 10 minutes as before. Record the start and end times.
- You should have three data tables:

Table 1 (Logger 1)

Surface type & Start and End times		CNR2 Net Shortwave	CNR2 Net Longwave
Variable	Time [MST]	K* [$W m^{-2}$]	L* [$W m^{-2}$]

Table 2 (Logger 2) – Variables in brackets are observed when flipped over.

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Surface type & Start and End times		PSP 1 Global (Reflected)	PSP 2 Diffuse (Reflected)	PIR Longwave In (Out)
Variable	Time [MST]	$K\downarrow$ ($K\uparrow$) [$W\ m^{-2}$]	$S\downarrow$ [$W\ m^{-2}$]	$L\downarrow$ ($L\uparrow$) [$W\ m^{-2}$]

Table 3 (Your field notes!)

Surface type & Start and End times		Ground Temperature	Temperature of clouds / sky (if possible)
Variable	Time [MST]	T_{surf} [$^{\circ}C$]	T_{sky} [$^{\circ}C$]

The Tables shows the type of data you should have, but you will have a number of observations for each data set. You can use the keypad to monitor the data in real time, but the data archived on the logger should be used for the later calculations.

- Repeat the previous steps for two different surface types.
- You should have 3*3 sets of data to analyze. Take the equipment back inside once you have all the data collected.

3. Interpreting the data

- Trim the data so you have clean sets of data, i.e., lop off the transitional periods when you moved from one location to another, including the first minute or last minute relative to your start and end times. Combine the tables into one for each surface type, matching up the time stamps.
- Calculate derivable variables: Direct Solar Radiation ($S\downarrow$), Net Radiation (Q^*) and other radiation quantities through subtraction; you will end up with several derived observations of the same variables, for example, you can calculate $L\uparrow$ during the first interval (PSPs and PIR facing up) as $L^*-L\downarrow$ and $L\downarrow$ during the second interval (PSPs and PIR facing down) as $L^*-L\uparrow$. Q^* can be calculated as the sum of the CNR2 measurements and as a sum of the individual short- and longwave components.
- *Question 9.* Plot the time series of all the shortwave and longwave components of the radiation balance for each of the 3 surface type observations. What is, in your opinion, the best way to plot the variables? Discuss briefly any variability observed in the dataset relative to the cloud cover conditions you observed. How large are the differences between the directly measured and calculated values for the different components?
- *Question 10.* Average the values collected (and derived) so that you have a single average value of $S\downarrow$, $D\downarrow$, $K\downarrow$, $K\uparrow$, K^* , $L\downarrow$, $L\uparrow$, L^* , Q^* , T_{surf} , T_{sky} for each of the 3 surface types. Calculate Albedo (α) and the ground and sky emissivities (ϵ_{surf} ; ϵ_{sky}) using observed longwave fluxes and temperatures and the Stefan-Boltzmann Law.
- *Question 11.* Do the calculated values differ from tabulated values listed in literature? To what extent do your estimates of albedo and surface and cloud/sky emissivity agree between each surface type? What might explain any discrepancies? Are these discrepancies due only to the changes in surface type, i.e., how constant were the conditions over the data collection period?
- *Question 12.* How do your observations compare to the estimates of incoming solar radiation and longwave surface radiation computed in questions 2 and 4?
- *Question 13.* Relate the observed values of net radiation to energy usage in daily life. How many TV's could be powered by the net radiative energy received per square meter? (Assume all received radiative energy could be made available).
- *Question 14.* Estimate the magnitude of Net Radiation (Q^*) during a clear sky night (Positive? ; Negative? Larger or smaller than during the day? Use basic knowledge and mathematical approximations.

4. Final Steps

- Create a lab report with all of your answers to Questions 1-13 . This must be typed.**
- Turn your lab report in by the following lecture.**