

UBC ATSC 303 2020W

Lab 9 – Solar and Earth Radiation (/49)

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Quick resources:

- Net Radiometer Introduction [Click here \(YouTube link\)](#)
- Reflection of Solar Radiation [Click here \(YouTube link\)](#)

Learning Goals

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

1. Be confident in your handling of the physical sensors and software covered in this lab.
2. Anticipate the types of output from these instruments.
3. Interpret and analyze real radiation data.
4. Reinforce the learning goals from the lecture and demo.

Background

Harrison: Ch. 9

SAFETY

- **DO NOT** move any equipment on your own.
- **DO NOT** touch the hot plate – it gets **VERY** hot!!
- **DO NOT** turn up the hot plate any higher than the “warm” setting, marked with pink nail polish on the dial.
- If a burn should occur, immediately run it under cold water and let an instructor know.

Method

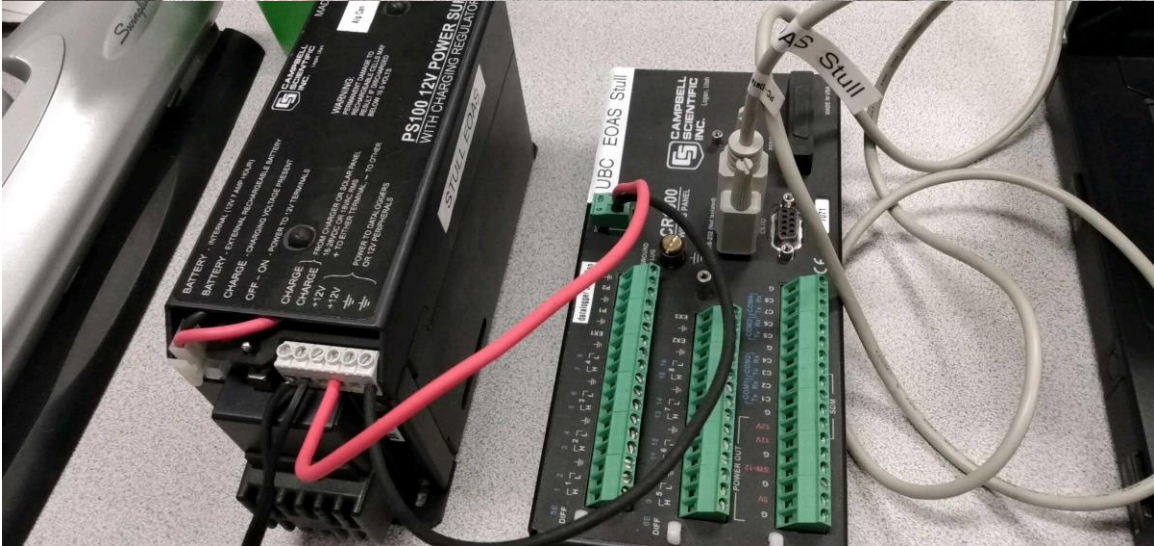
Part 0 – Powering the Datalogger and Connecting it to the Computer

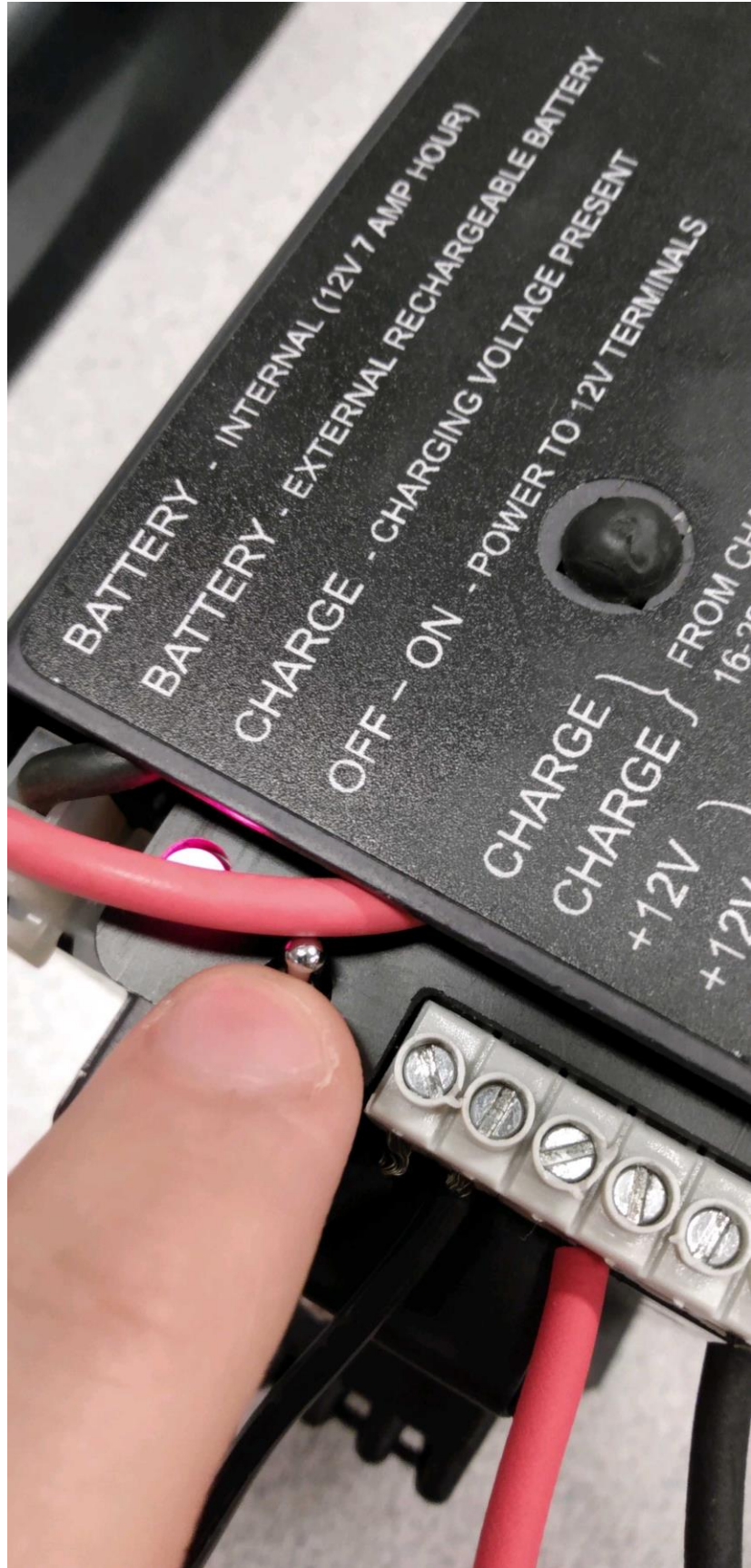
Equipment:

- CR1000 datalogger
- PC laptop with LoggerNet software
- 12V battery power supply
- Power adapter
- Serial cable
- Small screwdriver

1. With both the extension breaker and the Battery power output OFF, connect the Battery Charger to a power outlet. If you are connecting it directly to an outlet without the use of an extension, do Step 2 first.
2. Using a small screwdriver, connect the Battery Charger to the 12 V Battery. Turn the extension braker ON.
3. Connect the Power Adapter to the 12 V Battery. **Red** wire to the 12 V port, **Black** wire to the Ground port.
4. With the laptop ON, connect the RS232 cable to the Datalogger in the correct port, and then to the computer (for Durabooks the RS232 port is at the back).
5. With everything connected, make sure to turn the Battery power output ON.
6. Open the LoggerNet software and proceed to connect the computer to the Datalogger. Make sure you upload the correct program. Your final setup should be similar to this:







Method

Part 1 – Solar radiation simulation

Equipment:

- CNR1 net radiometer
- CR3000 datalogger
- PC laptop with LoggerNet software
- 12V battery supply
- Power adapter
- Serial cable
- Small screwdriver
- Desk lamp
- Multiple sheets of white paper
- Bubblewrap

1. Set up the CNR1 net radiometer with the desk lamp directly over the top and a bare desk underneath. It might help you to **note the timing** of the events in parts 1 and 2.
2. Apply “sun” (desk lamp) but make sure it is not too close to the radiometer since it gets hot. Observe the response in the shortwave readings.
3. Measure the downwelling (**CM3Up**) and upwelling (**CM3Dn**) “solar” radiation for a short time, e.g., a couple of minutes (the data is being sampled at a **2-second interval**).
4. Allow a “cloud” (bubblewrap, with as little of your hand as possible) to pass slowly between the “sun” and the instrument. Do this slowly, letting the “cloud” hover beneath the lamp for over 30 s before slowly moving it away. Observe the response.
5. Now change the “land surface” by spreading out multiple sheets of white paper underneath the radiometer on the desk. Observe the response. Also try re-

positioning the lamp so that a shadow would not be cast directly beneath the pyranometer.

6. Once more, measure the downwelling and upwelling “solar” radiation for a short time (you will not see a huge difference but there should be some changes).

Part 2 – IR radiation measurements

Equipment:

- CNR1 net radiometer
- IRR-P infrared thermometer
- CR3000 datalogger
- PC laptop with LoggerNet software
- 12V battery supply
- Power adapter
- Serial cable
- Small screwdriver
- Hot plate

1. Move the hot plate underneath the instruments (instructors will help with this).
2. Heat up the “land” as if on a sunny day by turning on the hot plate to the pink notch (denoted “WARM”). Observe the response. Measure the **IR temperature (TargTemp)** using the IRR-P thermometer and the **upwelling longwave radiation (CG3DnCo)** using the CNR1 for a short time, e.g. **a couple of minutes**.
3. Cool the “land” down as if the sun is setting, by decreasing the hot plate temperature halfway to “OFF”, observing the response. Record about **30 seconds** of measurements at this setting.
4. Simulate “sunset” by switching off the hot plate entirely, observing the response.

Lab questions (based on data files on the website)

1. Plot the downwelling and upwelling **shortwave radiation** data from **part 1**.

Indicate the following on your graph:

- The time period for the bare land surface.
- The time period when the cloud passed over the sensor.
- The time period for the white land surface. /6

2. Using the data collected in **part 1**, calculate the albedo of

- a. The bare desk, and
- b. The white paper.

You should average your data for a reasonable estimate. /4

3. Using the data collected in **part 2**, and showing your method:

- a. Estimate the “**ground**” **temperature** from the **upwelling longwave** radiation (CG3DnCo). You can assume that the ground is a black body. Plot this temperature trace on a graph. /4
- b. On the same graph, plot the **temperature** from the IR thermometer (careful with units!). How do the two temperature traces compare? If they are different, what is the main reason for this difference? /3

4. The CNR1 net radiometer used in this lab has a built-in platinum resistance temperature detector that measures the sensor body temperature, which is crucial to its operation. Why do you think this is? /2

Further questions (based on lectures, readings and additional data)

1. The four excel files (“WhistlerData.zip”) each represent one day of daytime radiation measurements from Rosie’s 2009 Whistler field season. Each file contains all four components of radiation: downwelling and upwelling shortwave and longwave. Plot **one graph** for **each day (four graphs)**, showing **all four components of radiation**. Include a legend and axes labelled with units. The x-axis should show the time, and the date can be the title of each graph. /8

2. **Visually** interpret your plotted data in order to match the dates to the following sky and weather conditions:
 - a. Mostly cloudy skies, especially in the morning. No precipitation.
 - b. Partly cloudy skies. No precipitation.
 - c. Clear skies. No precipitation.
 - d. Fog and snow.Include a brief discussion of how you made each match. /8

3. Based upon these radiation measurements, consider the sensor surroundings:
 - a. On the day with clear skies, why do you think the radiation data is not a smooth curve until late morning? /2
 - b. Do you think that Rosie’s Whistler site is an ideal location for a WMO climate station? Why? /1

4. Why is the magnitude of the downwelling longwave radiation noticeably less on the clear sky day than on the other days? /2

5. How could a properly calibrated pyranometer at the earth’s surface be subjected to an irradiance greater than that received on a cloudless day when the atmosphere is dust free? /1

6. Define the following terms:
 - a. Pyranometer /1
 - b. Pyrhelimeter /1
 - c. Pyrradiometer /1
 - d. Net pyrradiometer /1

7. The glass cover over a pyranometer serves to protect the sensor from the environment. What other functions does it have? /2

8. What measurement do you get by combining a tracking pyrhelimeter with a shaded pyranometer? /1

9. What measurement do you get by combining two pyranometers (one pointing up and one down) with two pyrgeometers (one up and one down)? /1

Appendix – CR3000 datalogger program used in this lab for your reference

```
'CR3000 Series Datalogger
' ATSC 303 Lab 9
' Program to calculate net radiation from Kipp and Zonen CNR1.
' Measures sensors every 2 seconds and stores every 10 seconds:
' SW radiation up and down, LW radiation up and down,
' body temperature (in degrees C and Kelvin), corrected LW up and down,
' total net radiation, 'sky' temperature and 'ground' temperature.
,
' Also calculates target temperature from Apogee IRR-P.
' Measures every 2 seconds and stores every 10 seconds:
' body temperature, mV output from thermopile and target temperature.
,
'date: 14 March 2011
'program author: Rosie Howard

'Declare Variables and Units for CNR1
Public batt_volt      'battery voltage
Public PTemp         'panel temperature

'Up sensors measure downwelling, Dn sensors measure upwelling
Public CM3Up         'SW radiation (pyranometer)
Public CM3Dn         'SW radiation
Public CG3Up         'LW radiation (pyrgeometer)
Public CG3Dn         'LW radiation
Public CNR1TC        'body temperature degrees C (from pt100 in CNR1 body)
Public CNR1TK        'body temperature degrees K (from pt100 in CNR1 body)
Public CG3UpCo       'temperature corrected LW up
Public CG3DnCo       'temperature corrected LW down
Public NetTot        'Total net radiation
Public SkytempC      'temp calculated from corrected downwelling LW radiation
Public GroundtempC  'temp calculated from corrected upwelling LW radiation

'Sensitivity of CNR1 for calibration, from Kipp&Zonen
Const Sens = 6.16    'microVolts/(W/metre^2)
Units batt_volt=Volts
Units PTemp=degC
Units CM3Up=W/metre^2
Units CM3Dn=W/metre^2
Units CG3Up=W/metre^2
Units CG3Dn=W/metre^2
Units CNR1TC=DegC
Units CNR1TK=K
Units CG3UpCo=W/metre^2
```

```
Units CG3DnCo=W/metre^2
Units NetTot=W/metre^2
Units SkytempC=degC
Units GroundtempC=degC
```

```
'Declare variables and units for IRR-P
```

```
Public SBTemp      'surface body temperature of IR therm
Public TmV         'voltage output of thermistor
Public TargTemp    'target temperature; calculated by adding the sensor body
                  'temperature raised to the fourth power and the mV output
                  'multiplied by the slope (m) and the y-intercept (b), then the
                  'fourth root of this sum
```

```
Dim Tsqr1, Tsqr2, SBTempK, m, b, TargTempK
```

```
Units SBTemp=degC
Units TmV=mV
Units TargTemp=degC
```

```
'Declare Constants. These values are unique to individual sensors. Values here are
'obtained from CRBasic IRR-P 1242 Custom Coefficients document received with the
'sensor.
```

```
'Calibration date:20-Dec-2007.
```

```
Const mC2=16433.1
Const mC1=11153600
Const mC0=1471420000
Const bC2=70373.1
Const bC1=-2577420
Const bC0=-3878910
```

```
'Data tables
```

```
'Define data table for CNR1
```

```
DataTable (CNR1,True,-1)
    DataInterval (0,10,Sec,0)
    Average(1,CM3Up,FP2,False)
    Average(1,CM3Dn,FP2,False)
    Average(1,CG3Up,FP2,False)
    Average(1,CG3Dn,FP2,False)
    Average(1,CNR1TC,FP2,False)
    Average(1,CNR1TK,FP2,False)
    Average(1,CG3UpCo,FP2,False)
    Average(1,CG3DnCo,FP2,False)
    Average(1,NetTot,FP2,False)
    Average(1,SkytempC,FP2,False)
    Average(1,GroundtempC,FP2,False)
EndTable
```

'Define data table for IRR-P

```
DataTable (IRR-P,True,-1)
  DataInterval (0,10,Sec,0)
  Average (1,SBTemp,FP2,False)
  Average (1,TmV,FP2,False)
  Average (1,TargTemp,FP2,False)
Endtable
```

'Main Program

```
BeginProg
  Scan (2,Sec,1,0)
  'Default datalogger battery voltage measurement batt_volt:
    Battery (Batt_volt)
    PanelTemp (PTemp,250)

  'Instructions for CNR1 Net Radiometer
  'CNR1 Net Radiometer measurements CM3Up, CM3Dn, CG3Up, CG3Dn,
  'CNR1TC, CNR1TK, CG3UpCo, CG3DnCo,NetTot:
  '1000/Sens: '1000' converts mV to microvolts, dividing by Sens converts
  'microns to W/metre^2
    VoltDiff(CM3Up,1,mV20,1,True,0,_60Hz,1000.0/Sens,0)
      'wire colours: high red, low blue, jump
    VoltDiff(CM3Dn,1,mV20,2,True,0,_60Hz,1000.0/Sens,0)
      'wire colours: high thin white, low thin black, jump
    VoltDiff(CG3Up,1,mV20,3,True,0,_60Hz,1000.0/Sens,0)
      'wire colours: high grey, low yellow, jump
    VoltDiff(CG3Dn,1,mV20,4,True,0,_60Hz,1000.0/Sens,0)
      'wire colours: high brown, low green, ground thick black

  BrHalf4W(CNR1TC,1,mV50,mV50,5,Vx2,1,4200,True,True,0,250,1.0,0)
    'used to make a 4 wire half bridge measurement
    '4WPB100 connected to excitation channel
    'two channels needed for 4WPB100 and PT100
    'wire colours: 4WPB100 in channel 1: low red, ground blue.
    'wire colours: PT100 panel temperature in channel 2: high
    'yellow, low green, ground thick black
  PRT (CNR1TC,1,CNR1TC,1,0)
    'Calculates temperature from the resistance of an RTD (thermistor)
    CNR1TK=CNR1TC+273.15 'body temperature of CNR1 in Kelvin
    CG3UpCo=CG3Up+5.67*10^-8*CNR1TK^4      'calibrated downwelling LW
    SkytempC=(CG3UpCo/(5.67*10^-8))^(1/4) - 273.15
    CG3DnCo=CG3Dn+5.67*10^-8*CNR1TK^4      'calibrated upwelling LW
    GroundtempC=(CG3DnCo/(5.67*10^-8))^(1/4) - 273.15
    NetTot=(CM3Up-CM3Dn) + (CG3UpCo-CG3DnCo)
      'net SW + net LW (positive for net downwelling)
```

```

'Instructions for IR thermometer measurement
'Instruction to measure the sensor body temperature
    Therm109 (SBTemp,1,17,Vx1,0,_60Hz,1.0,0)
'Instruction to measure the mV output of the thermopile
    VoltDiff (TmV,1,AutoRange,8,True,0,_60Hz,1.0,0)

'Calculation of m (slope) and b (intercept) coefficients for
'target temperature calculation
    m = mC2*SBTemp*SBTemp + mC1*SBTemp + mC0
    b = bC2*SBTemp*SBTemp + bC1*SBTemp + bC0
'Target temperature calculation based on m and b coefficients
    SBTempK = SBTemp + 273.15
    Tsqr1 = SBTempK*SBTempK*SBTempK*SBTempK + m*TmV + b
    Tsqr2 = SQR(Tsqr1)
    TargTempK = SQR(Tsqr2)
    TargTemp = TargTempK - 273.15

'Call Output Tables
    CallTable(CNR1)
    CallTable(IRR-P)
NextScan
EndProg

```