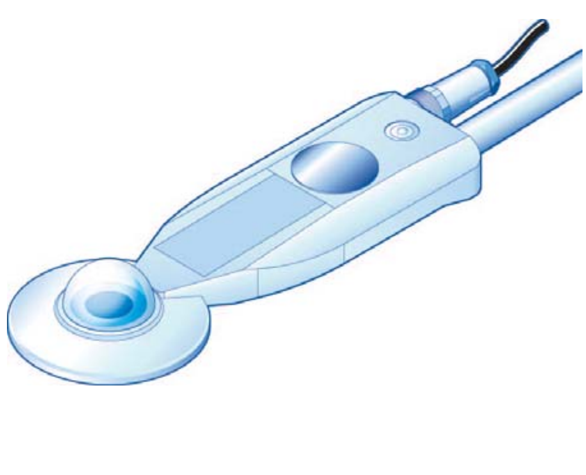
INSTRUCTION MANUAL

CNR2 Net Radiometer

July 2008



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CNR2 Net Radiometer

1. General Description

The CNR2 Net Radiometer is intended for the analysis of the radiation balance of solar and far infrared radiation. The most common application is the measurement of net (total) radiation at the earth's surface.

The CNR2 design is such that both the upward facing and the downward-facing instruments measure the energy that is received from the hemisphere. The short-wave sensor, or pyranometer, has a field of view of 180 degrees on the upper and 150 degrees on the lower detector. The long wave sensor, or pyrgeometer, has a field of view of 150 degrees on the upper and the lower detector. The output is expressed in Watts per square meter. The total spectral range that is measured is roughly from 0.3 to 40 micrometers. This spectral range covers both the solar radiation, 0.3 to 2.8 micrometers, and the far infrared radiation, 4.5 to 42 micrometers.

The design of the CNR2 is such that solar radiation and far infrared radiation are measured separately. Solar radiation is measured by two pyranometers, one for measuring incoming solar radiation from the sky, and the other, which faces downward, for measuring the reflected solar radiation. The final result from these two pyranometers is net short-wave radiation.

Far infrared radiation is measured by two pyrgeometers, one for measuring the far infrared radiation from the sky, the other from the soil surface. Net long-wave radiation is a final result of measurements from those two detectors.

Additional information on the CNR2 sensor can be found in the Kipp & Zonen CNR2 Manual. The primary intent of this manual is to provide information on interfacing the CNR2 to Campbell Scientific dataloggers.

2. Sensor Specifications

2.1 CNR2 Specifications

See the Kipp & Zonen manual for additional specifications.

Sensor response time:	95% <10s
Temperature dependence of sensitivity:	(-10°C to +40°C) <5%
Sensor asymmetry:	<5%
Sensor sensitivities:	10 to 20 $\mu V/W/m^2$
Sensitivity change per year:	<1%
Tilt error:	<1%
Uncertainty in daily total:	<10%
Cable length:	Customer’s choice from 3 to 100 ft.
Weight:	250 g (add about 300g for each 30ft of cable)

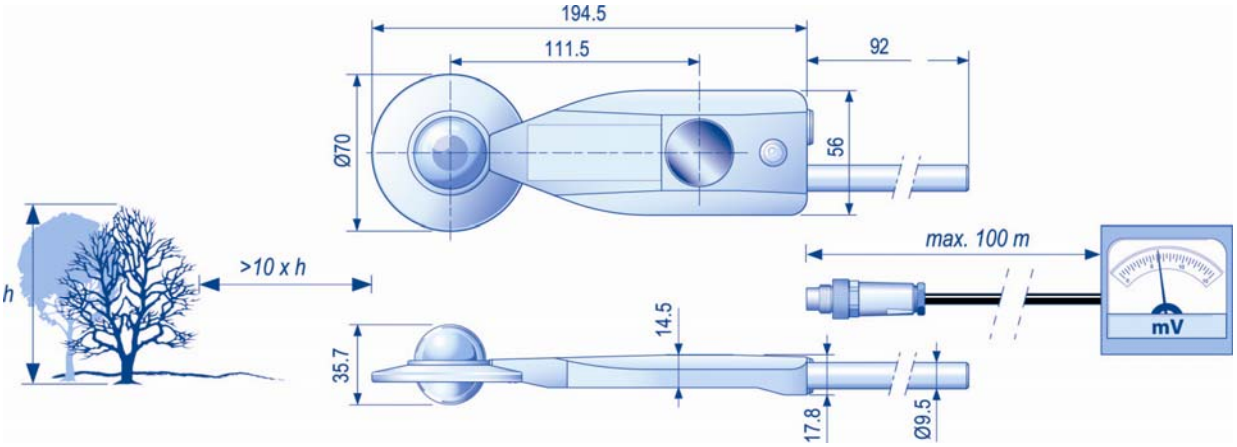


FIGURE 2-1. The Dimensions of the CNR2

2.2 Pyranometer Specifications

Specifications that are part of the ISO classification:

Response time 95%:	<10 s
Non-stability:	<1% change per year
Non-linearity:	Max. dev. 2.0% (0-1000 W m^{-2})
Directional error:	Max. 25 W m^{-2} at 1000 W m^{-2}
Spectral selectivity:	Max. dev. 5% (310-2800 nm)
Temperature dependence of sensitivity:	<5% (-10 to +40^{o}C)
Tilt response:	Max. dev. <1%
Field of view:	Upper =180° ; Lower=150°
Zero offset: Type A; 200 W/m^2 FIR	<15 W/m^2
Overall ISO classification:	Second class
Sensitivity:	10 - 20 µV/(W m^{-2})
Operating temperature:	-40°C to +80°C
Spectral range:	310-2800 nm (50% points)
Expected signal range for atmospheric application:	0 - 50 mV typical
Expected accuracy for daily sums:	Uncertainty < 10%

2.3 Pyrgeometer Specifications

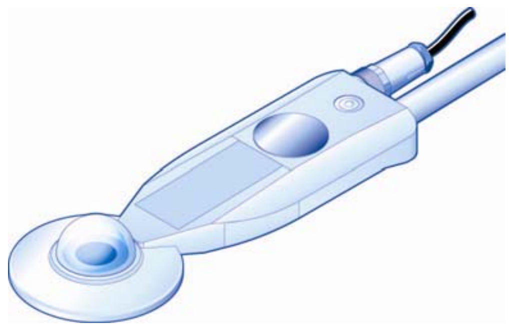
Response time 95%:	<10 s
Non-stability:	< 1% change per year
Non-linearity:	Max. dev. <1% (-250 to +250 W m^{-2}) net irradiance
Temperature dependence of sensitivity:	<5% (-10°C to +40°C)
Tilt response:	Max. <1% when facing downwards
Field of view:	Upper =150° ; Lower=150°
Sensitivity:	10 - 20 µV/(W m^{-2})
Zero offset: Type B:	25 W
Window heating offset:	<25 W/m^2
Operating temperature:	-40°C to +80°C
Temperature range for specified behavior:	-10°C to +40°C
Measurement range:	-250 to +250 W m^{-2}
Spectral range:	4.5 to 42 µm
Expected signal range for atmospheric application:	-5 to 5 mV
Expected accuracy for daily sums:	Uncertainty < 10%

3. Installation

For measurement of the net radiation, it is important that the instrument is located in a place that is representative of the entire region that one wishes to study.

When installed on a mast, the preferred orientation should be such that no shadow is cast on the net radiometer at any time during the day. In the Northern Hemisphere, this implies that the net radiometer should be mounted south of the mast. In the Southern Hemisphere, the net radiometer should be mounted north of the mast.

It is suggested that the CNR2 is mounted at a height of at least 1.5 meters above the surface to avoid the shading effects of the instruments on the soil and to promote spatial averaging of the measurement. If the instrument is H meters above the surface, 99% of the input of the lower sensors comes from a circular area with a radius of 10 H. Shadows or surface disturbances with radius <0.1 H will affect the measurement by less than 1%.



See Appendix A to put together the CNR2 mounting kit (Part # C2213) and to finish the CNR2 mounting procedures.

For installation in buildings or in solar energy applications, one will often have to mount the CNR2 parallel to the surface that is being studied. This may be in a tilted or a vertical position. The sensitivity of the radiometers will be affected, but only in a minor way. This is specified as the so-called tilt effect. From the specifications one can see that the tilt effect (this is change in sensitivity) remains within 1%.

4. Using the CNR2 in the Two Separate Components Mode (2SCM)

In the 2SCM configuration, net short-wave and net long-wave signals are measured separately. Calculation of net radiation can be done by the datalogger, or later by the computer from the radiation data.

The two pyranometers will measure the solar radiation, both incoming and reflected; the two pyrgeometers will measure the far infrared radiation. However, only one output for solar (net) and one output for infrared (net) will be given as a result of the CNR2 measurements.

The following paragraphs describe how one should treat the instrument, and how different parameters like net solar radiation, net far infrared radiation, and net (total) radiation can be calculated.

4.1 Measuring Solar Radiation with the Pyranometers

Measuring with the upward-facing pyranometer the so-called global (solar) radiation is measured. The downward-facing pyranometer measures the reflected solar radiation. When the final output of the net radiation is made by the sensor, the reflected radiation is subtracted from the global radiation.

$$E_{NETSW} = \frac{U_{SW}}{S_{SW}} \tag{4.1}$$

Where, U_{SW} is output voltage in μV

S_{SW} is sensitivity in $\frac{\mu V}{W/m^2}$

4.2 Measuring Far Infrared Radiation with the Pyrgeometers

The downward-facing pyrgeometer measures the far infrared radiation that is emitted by the ground. The upward-facing pyrgeometer measures the far infrared radiation from the sky.

The long-wave infrared signal output is the difference between incoming and outgoing infrared radiation.

The calculation of the far infrared pyrgeometer irradiance, E, is done according to the following equation:

$$E_{NETLW} = \frac{U_{LW}}{S_{LW}} W/m^2 \tag{4.2}$$

Where, U_{LW} is output voltage in μV

S_{LW} is sensitivity in $\frac{\mu V}{W/m^2}$

4.3 Calculation of the Net Radiation

In the two separate component mode, net radiation, E_{NET}, can be calculated using the sensor measurement results for net solar and net infrared:

$E_{NET} = E_{NETSW} + E_{NETLW}$

5. Wiring

The two radiation outputs from CNR2 Net Radiometer can be measured using differential or single-ended inputs on the datalogger. A differential voltage measurement (Instruction 2 for old CR10X loggers) is recommended because it has better noise rejection than a single-ended measurement.

FIGURE 5-1. Pin Layout on Campbell Scientific Black Cable

TABLE 5-1. CR800, CR850, CR1000, CR3000, and CR5000 Connections for Differential Measurement

Function	Color	CR800/CR850 CR1000/CR3000/CR5000
Pyranometer Signal	White	Differential Input (H)
Pyranometer Reference	Blue	Differential Input (L)
Pyrgeometer Signal	Brown	Differential Input (H)
Pyrgeometer Reference	Black	Differential Input (L)
Shield	Clear	⏚

TABLE 5-2. Datalogger Connections for Differential Measurement on Old CSI Loggers

Function	Color	CR10X,CR510	CR23X	21X/CR7
Pyranometer Signal	White	Differential Input (H)	Differential Input (H)	Differential Input (H)
Pyranometer Reference	Blue	Differential Input (L)	Differential Input (L)	Differential Input (L)
Pyrgeometer Signal	Brown	Differential Input (H)	Differential Input (H)	Differential Input (H)
Pyrgeometer Reference	Black	Differential Input (L)	Differential Input (L)	Differential Input (L)
Shield	Clear	G	⏚	⏚

If the CNR2 Net Radiometer came directly from the manufacturer, Kipp and Zonen, color of connection cable would be yellow and wires would have different colors. Figures 5-1 and Table 5-3 are showing pin layout for that case.

FIGURE 5-2. Pin Layout on Kipp & Zonen Original Cable

TABLE 5-3. Wiring Diagram on Kipp & Zonen Original Yellow Cable

Connector pin	Wire color	Function	Parameter	Connected with
1	Red	+	Net short wave	+ (Hi)
2	Blue	-		- (Low)
3	Green	+	Net long wave	+ (Hi)
4	Yellow	-		- (Low)
Shield	Shield	Housing		Ground *

6. Datalogger Programming

The CNR2 outputs two voltages that typically range from 0 to 15 mV for the pyranometers, and ±5 mV for the pyrgeometers. A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement. If differential channels are not available, single-ended measurements can be used. The acceptability of a single-ended measurement can be determined by simply comparing the results of single-ended and differential measurements made under the same conditions.

6.1 Calibration Factor

Each CNR2 is provided with a ‘Certificate of Calibration’ by the manufacturer that shows the sensor serial number and ‘sensitivity’, or calibration factor. The serial number and sensitivity are also shown on a label attached to the sensor.

The calibration factor is in units of $\mu V/(W\ m^{-2})$, which needs to be converted to units of $(W\ m^{-2})/mV$ for the multiplier parameter in the datalogger program.

To convert the units divide the calibration factor into 1000. For example, if the calibration factor is 22.0 for short-wave radiation and 11.6 for long-wave radiation sensors conversion will look like:

SW: 1000/22.0 $\mu V/(W\ m^{-2})$ = 45.4546 (W m-2)/mV.

LW 1000/11.6 $\mu V/(W\ m^{-2})$ = 86.2069 (W m-2)

So multipliers are 45.4546 for short-wave and 86.2069 $(W\ m^{-2})/mV$ for long-wave radiation.

6.2 Example Programs

6.2.1 Example Program for CR1000 Datalogger

```
'Example CNR2 Net Radiometer program for CR1000 datalogger

'Each CNR2 is provided with a 'Certificate of Calibration' by the manufacturer
'that shows the sensor serial number and 'sensitivity', or calibration factors.
'The serial number and sensitivity are also shown on a label attached to the sensor.
'The calibration factor is in units of uV/(W m-2), which needs to be converted to
'units of (W m-2)/mV for the multiplier parameter in the datalogger program.
'For this example calibration factor for SW is 22.0 uV/(W m-2), and LW is 11.6 uV/(Wm-2).
'The multipliers are:
'SW: 1000/22.0 = 45.4546 (W m-2)/mV.
'LW" 1000/11.6 = 86.2069 (W m-2)/mV.

'*** Wiring ***

'1H Shortwave signal + (white)
'1L Shortwave signal - (blue)
'2H Longwave signal + (brown)
'2L Longwave signal - (black)
'Shield (ground)

'Declare Variables and Units
Public Net_Shortwave
Public Net_Longwave
Units Net_Shortwave=Wm-2
Units Net_Longwave=Wm-2

'Define Data Tables
DataTable(Table1,True,-1)
    DataInterval(0,1,Min,10)
    Sample(1,Net_Shortwave,FP2)
    Sample(1,Net_Longwave,FP2)
EndTable

DataTable(Table2,True,-1)
    DataInterval(0,60,Min,10)
    Minimum(1,Net_Shortwave,FP2,False,True)
    Maximum(1,Net_Shortwave,FP2,False,True)
    Average(1,Net_Shortwave,FP2,False)
```

```
      Minimum(1,Net_Longwave,FP2,False,True)
      Maximum(1,Net_Longwave,FP2,False,True)
      Average(1,Net_Longwave,FP2,False)
EndTable

'Main Program
BeginProg
      Scan(1,Sec,1,0)
            'CNR2 Net Radiation Measurements
            VoltDiff(Net_Shortwave,1,mV25,1,True,200,250,45.4546,0.0)
            VoltDiff(Net_Longwave,1,mV25,2,True,0,250,86.2069,0.0)
            'Call Data Tables and Store Data
            CallTable(Table1)
            CallTable(Table2)
      NextScan
EndProg
```

6.2.2 Example Program for CR10X Datalogger

```
;Example CNR2 Net Radiometer program for CR10X datalogger
;
;Each CNR2 is provided with a 'Certificate of Calibration' by the manufacturer
;that shows the sensor serial number and 'sensitivity', or calibration factors.
;The serial number and sensitivity are also shown on a label attached to the sensor.
;The calibration factor is in units of uV/(W m-2), which needs to be converted to
;units of (W m-2)/mV for the multiplier parameter in the datalogger program.
;For this example calibration factor for SW is 22.0 uV/(W m-2), and LW is 11.6 uV/(Wm-2).
;The multipliers are:
;SW: 1000/22.0 = 45.4546 (W m-2)/mV.
;LW" 1000/11.6 = 86.2069 (W m-2)/mV.

;*** Wiring ***

; 1H Shortwave signal + (white)
; 1L Shortwave signal - (blue)
; 2H Longwave signal + (brown)
; 2L Longwave signal - (black)

;
*Table 1 Program
   01:  1.0000        Execution Interval (seconds)

; Measure Net Shortwave Radiation
1:  Volt (Diff) (P2)
   1:   1             Reps
   2:   23            25 mV 60 Hz Rejection Range
   3:   1             DIFF Channel
   4:   1             Loc [ Net_SW    ]
   5:   45.4546       Multiplier
   6:   0.0           Offset
```

```
; Measure Net Longwave Radiation
2:  Volt (Diff) (P2)
   1:   1              Reps
   2:   22             7.5 mV 60 Hz Rejection Range
   3:   2              DIFF Channel
   4:   2              Loc [ Net_LW    ]
   5:   86.2069        Multiplier
   6:   0.0            Offset
;
;Output data to the final storage every minute
;
3:  If time is (P92)
   1:   0              Minutes (Seconds --) into a
   2:   1              Interval (same units as above)
   3:   10             Set Output Flag High (Flag 0)

4:  Set Active Storage Area (P80)
   1:   1              Final Storage Area 1
   2:   101            Array ID

5:  Real Time (P77)
   1:   1220           Year,Day,Hour/Minute (midnight = 2400)

6:  Sample (P70)
   1:   2              Reps
   2:   1              Loc [ Net_SW    ]

;Output data to the final storage every 60 minutes
;
7:  If time is (P92)
   1:   0              Minutes (Seconds --) into a
   2:   60             Interval (same units as above)
   3:   10             Set Output Flag High (Flag 0)

8:  Set Active Storage Area (P80)
   1:   1              Final Storage Area 1
   2:   102            Array ID

9:  Real Time (P77)
   1:   1220           Year,Day,Hour/Minute (midnight = 2400)

10:  Minimum (P74)
   1:   1              Reps
   2:   10             Value with Hr-Min
   3:   1              Loc [ Net_SW    ]

11:  Maximum (P73)
   1:   1              Reps
   2:   10             Value with Hr-Min
   3:   1              Loc [ Net_SW    ]

12:  Average (P71)
   1:   1              Reps
   2:   1              Loc [ Net_SW    ]
```

```
13:  Minimum (P74)
  1:    1              Reps
  2:    10             Value with Hr-Min
  3:    2              Loc [ Net_LW    ]

14:  Maximum (P73)
  1:    1              Reps
  2:    10             Value with Hr-Min
  3:    2              Loc [ Net_LW    ]

15:  Average (P71)
  1:    1              Reps
  2:    2              Loc [ Net_LW    ]

*Table 2 Program
  01:  10.0000         Execution Interval (seconds)

1:  Serial Out (P96)
  1:    71             Storage Module

*Table 3 Subroutines

End Program
```

7. Calibration

The CNR2 should be recalibrated every two years, or as an alternative, by letting a higher standard run parallel to it over a two-day period and then comparing the results. For comparison of pyranometers, one should use a clear day. For comparison of pyrgeometers, one should compare nighttime results. Deviations of more than 6% can be used to correct the calibration factors.

8. Maintenance

Keep domes and windows clean using water or alcohol. Readings are reduced if domes and/or windows are not clean.

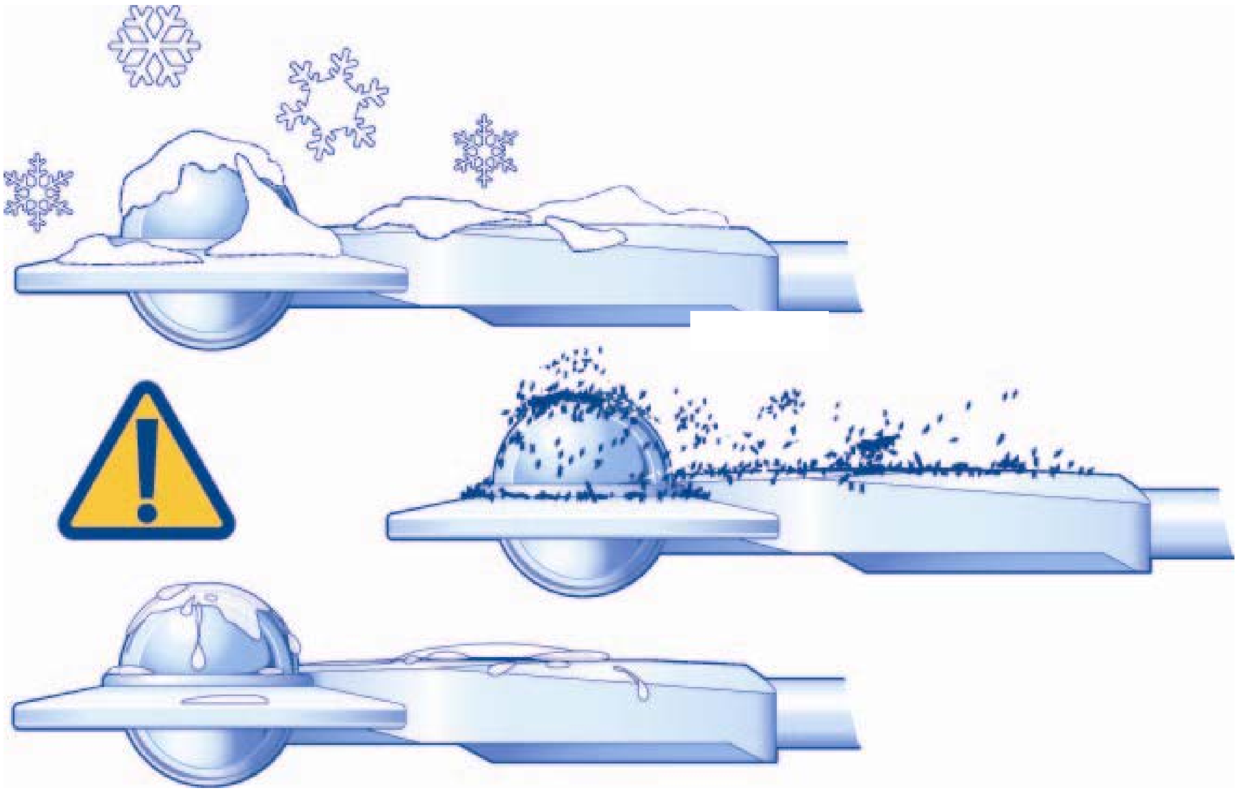


FIGURE 8-1. Dirt, Rain or Snow on CNR2 Sensors will Reduce the Readings

Keep instrument leveled at all times during the measurements.

FIGURE 8-2. Keep CNR2 Net Radiometer Leveled at All Times

Recommended drying cartridge replacement interval is every 6 months.

FIGURE 8-3. Replace Drying Cartridge Every Six Months (first replacement comes with CNR2)

9. Typical Values

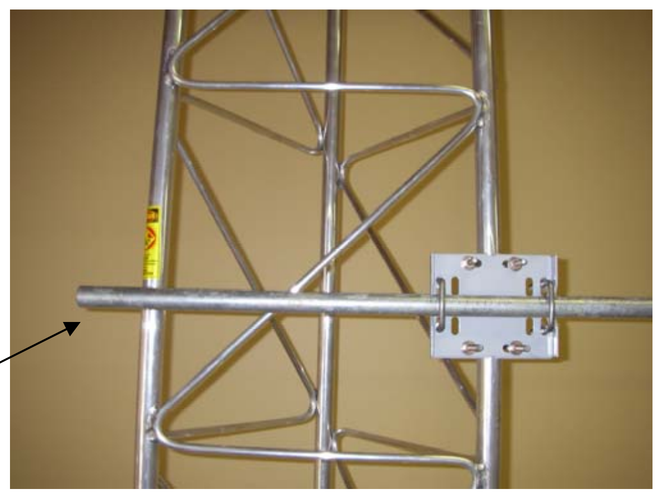
TABLE 9-1. Typical Values from CNR2 Net Radiometer

Wavelength	Fully Clouded	Sunny, Partly Clouded	Clear and Sunny
Net short wave	0 to 120 W/m²	50 to 500 W/m²	200 to 1000 W/m²
Net long wave	–25 to +25 W/m²	–50 to +50 W/m²	–50 to –200 W/m²

Appendix A. Assembly Instructions for CNR2 Mounting Kit

WARNING: Over-tightening of hardware may case damage to sensor mount. Be cautious when securing hardware.

Step 1. Pre-assemble C128V mounting bracket and attach to tripod mast or tower leg. This will require the use of a ½” wrench.

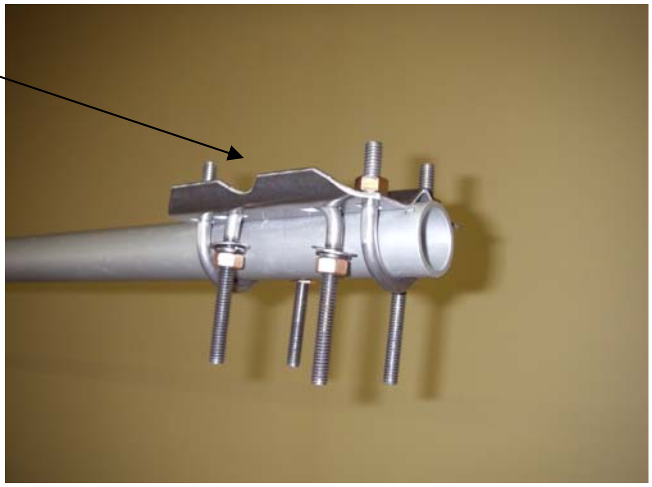


CM206

Step 2. The CM206 is comprised of 2 parts; the CM210 mounting bracket and a 6’ section of 1” diameter pipe. After moving the CM210 to one end of the crossarm insert the CM206 into the C128V and secure, then check that the crossarm is level and adjust as necessary.

NOTE: When mounting the CM206 to a tripod, the best practice is to orientate the crossarm so that the sensor will be located between two of the tripod legs. This will help avoid any reflections from the tripod legs.

CM210



Step 3. Remove large U-bolt clamp from the CM210 and replace with supplied V-bolts and hardware. Loosely secure the CM210 on top of the CM206 crossarm as level as possible.

Step 4. Attach mounting rod to CNR2. Insert rod into the CM210 mounting plate and loosely secure. Be sure CNR2 is orientated south, and then level the CNR2 using bubble level on top of sensor. Once level, secure all CM210 mounting hardware.