INSTRUCTION MANUAL

CNR2 Net Radiometer

Revision: 5/10

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CNR2 Net Radiometer

1. General Description

The CNR2 Net Radiometer is intended for the analysis of the radiation balance of short-wave and long-wave infrared radiation. The most common application is the measurement of total net 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 short-wave radiation and long-wave radiation are measured separately. Short-wave radiation is measured by two pyranometers, one for measuring incoming short-wave radiation from the sky, and the other, which faces downward, for measuring the reflected short-wave radiation. The final result from these two pyranometers is net short-wave radiation.

Long-waveradiation is measured by two pyrgeometers, one for measuring the long-wave 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

Response time:	<10s
Temperature dependence of sensitivity (-10°C to +40°C):	<5%
Sensor asymmetry:	<5%
Sensitivities:	10 to 20 μV/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. (Recommended are 50, 75, and 100 ft)
Weight:	250 g (add about 300g for each 30ft of cable)

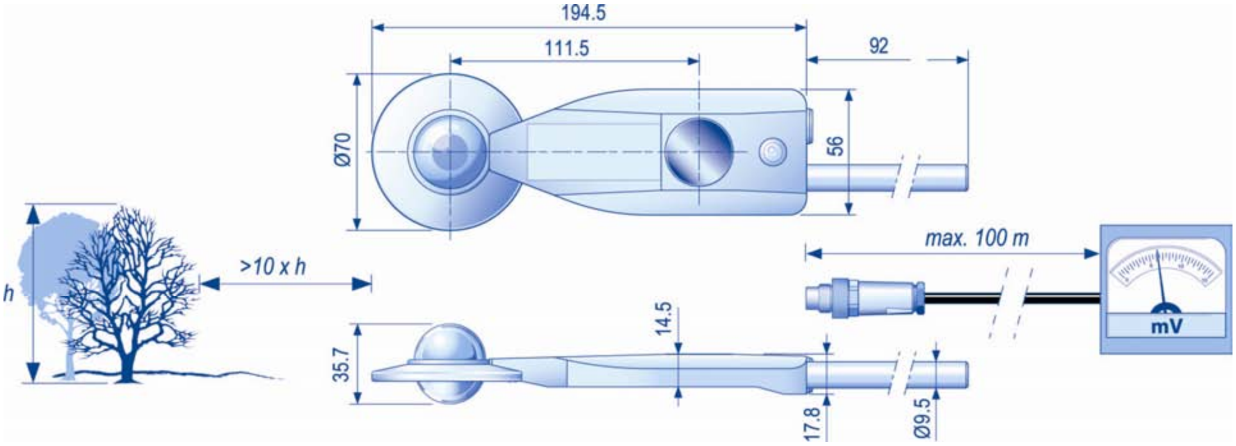

FIGURE 2-1. The Dimensions of the CNR2

2.2 Pyranometer Specifications

Spectral range:	310 to 2800 nm
Zero offset: Type A; 200 W/m^2 FIR	<15 W/m^2
Field of view for upper detector:	180°
Field of view for lower detector:	150°
Directional error:	<20 W m^{-2}
Non-linearity (0-1000 W m^{-2}) net irradiance:	<2.0%

2.3 Pyrgeometer Specifications

Spectral range:	4.5 to 42 µm
Field of view of upper detector:	150°
Field of view of lower detector:	150°
Non-linearity (-250 to +250 W m^{-2}) net irradiance:	<1%

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 study region.

Install the CNR2 such that no shadow is cast on the net radiometer at any time during the day. In the Northern Hemisphere, mount the CNR2 south of the mast. In the Southern Hemisphere, mount the CNR2 north of the mast (see Figure 3-1).

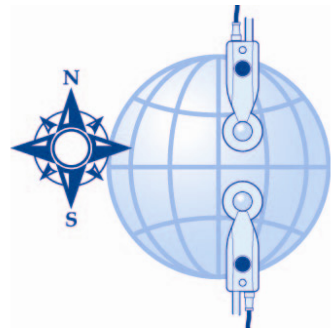

FIGURE 3-1. Mounting According to Hemisphere

Mount the CNR2 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%.

The 26120 mounting bracket kit is used to attach the CNR2 directly to a vertical pole or to a CM202, CM204, or CM206 crossarm.

NOTE A 26127 mounting rod is required to attach the CNR2 to a pole or crossarm via the 26120 mounting kit. The 26127 mounting rod began shipping with the CNR2 in February 2010. This mounting rod will need to be purchased if the CNR2 was shipped prior to February 2010.

Mount the sensor as follows:

1. Screw the 26127 mounting rod into the base of the CNR2.

2. Attach the 26120 mounting bracket to the pole or crossarm, using the kit's U-bolts (see Figure 3-2).

3. Insert the 26127 mounting rod into the mounting block of the 26120 mounting bracket kit. Make sure the sensor points in the direction of the arrows that appear after the word "SENSOR" on top of the bracket (see Figure 3-2). Perform a coarse leveling of the sensor using the bubble level on the top of the CNR2, and tighten the four screws on top of the mounting bracket to properly secure the mounting rod so that it does not rotate.

NOTE Do not attempt to rotate the instrument using the sensor heads, or you may damage the sensor; use the mounting rod only.

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4. Perform the fine leveling using the two spring-loaded leveling screws: one on the front and the other on the back of the bracket.

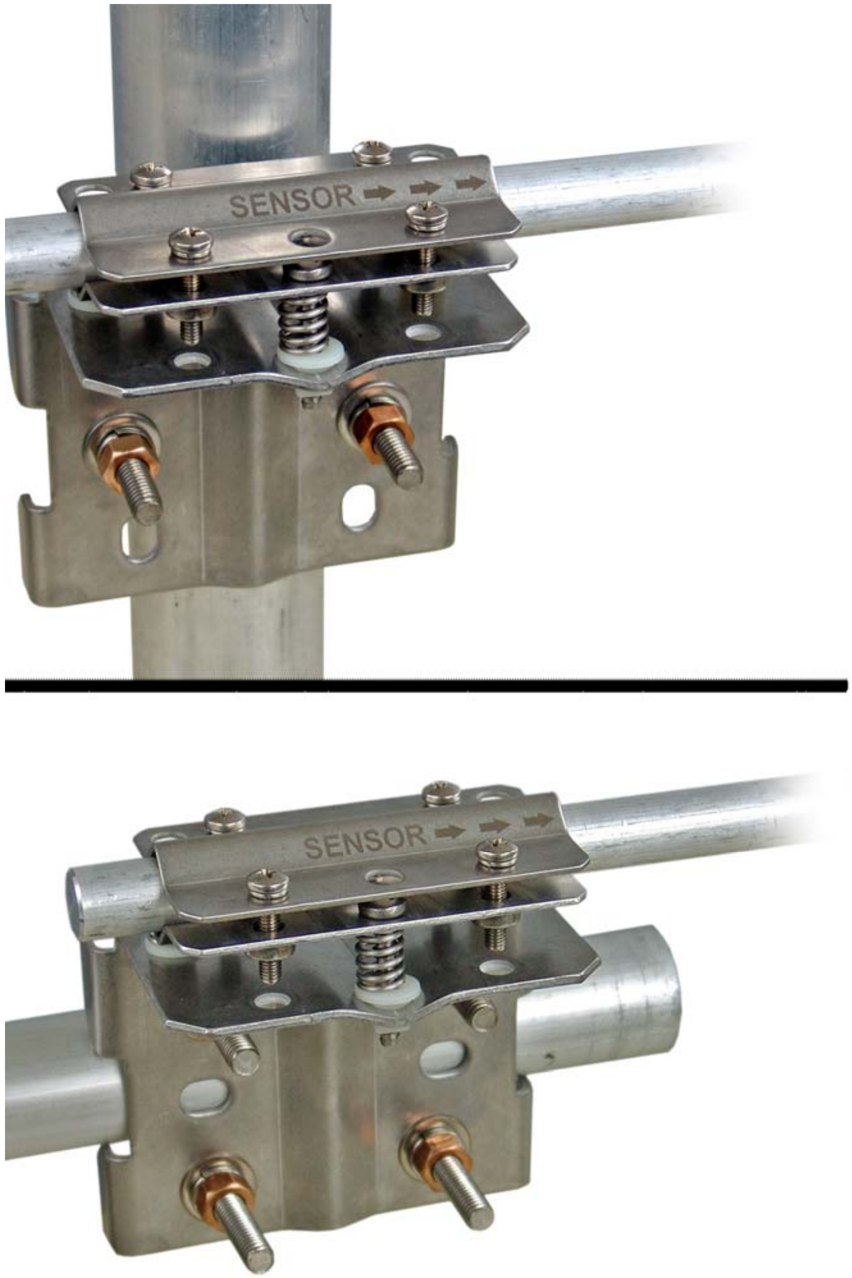

FIGURE 3-2. The CNR2 mounted to a pole (top) and crossarm (bottom) via the 26120 Mounting Bracket Kit.

For installation in buildings or in solar energy applications, users 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, notice that the tilt effect (this is change in sensitivity) remains within 1%.

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

The two pyranometers will measure the short-wave radiation (incoming from the sky and reflected from the soil surface); the two pyrgeometers will measure the long-wave radiation (incoming from the sky and reflected from the soil surface). However, only one output for short-wave radiation (net short-wave) and one output for long-wave radiation (net long-wave) will be given as a result of the CNR2 measurements.

4.1 Measuring Solar Radiation with the Pyranometers

The upward-facing pyranometer measures incoming short-wave (global or solar) radiation. The downward-facing pyranometer measures the reflected short-wave (solar) radiation. When the final output of the net solar radiation is made by the sensor, the reflected radiation is subtracted from the global radiation.

To find the net short-wave radiation, divide the measured short-wave output from the sensor by its sensitivity.

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

Where, E_{NETSW} is the net short-wave radiation in W m^{-2}
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 upward-facing pyrgeometer measures the far infrared radiation from the sky. The downward-facing pyrgeometer measures the far infrared radiation that is emitted by the ground.

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

To find the net long-wave radiation, divide the measured long-wave output from the sensor by its sensitivity.

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

Where, E_{NETLW} is the net long-wave radiation in W m^{-2}
U_{LW} is output voltage in μV

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

4.3 Calculation of the Net Solar Radiation

The net radiation, E_{NET}, is calculated using the sensor measurement results for net short-wave radiation and net long-wave radiation. The net radiation is the difference between the net short-wave and net long-wave radiation.

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

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 (VoltSE instruction in CRBasic or Instruction 2 in Edlog) 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. CRBasic Datalogger Connections for Differential Measurement

Heat Shrink Label	Color	Pin Number	CR800/CR850 CR1000/CR3000/CR5000
Pyranometer Sig	White	1	Differential Input (H)
Pyranometer Ref	Blue	2	Differential Input (L)
Pyrgeometer Sig	Brown	3	Differential Input (H)
Pyrgeometer Ref	Black	4	Differential Input (L)
Shield	Clear		⏚

TABLE 5-2. Edlog Datalogger Connections for Differential Measurement				
Heat Shrink Label	**Color**	**CR10X, CR510**	**CR23X**	**21X/CR7**
Pyranometer Sig	White	Differential Input (H)	Differential Input (H)	Differential Input (H)
Pyranometer Ref	Blue	Differential Input (L)	Differential Input (L)	Differential Input (L)
Pyrgeometer Sig	Brown	Differential Input (H)	Differential Input (H)	Differential Input (H)
Pyrgeometer Ref	Black	Differential Input (L)	Differential Input (L)	Differential Input (L)
Shield	Clear	G	⏚	⏚

If the CNR2 Net Radiometer was purchased from Kipp and Zonen, the color of the connection cable is yellow and have the pin out shown in Figure 5-2.

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

TABLE 5-3. Campbell Scientific Cable vs. Kipp & Zonen Cable	
Campbell Scientific Cable	**Kipp & Zonen Cable**
White	Red
Blue	Blue
Brown	Green
Black	Yellow
Clear	Clear

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. Use a differential voltage measurement 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 shipped 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 determine the multiplier, 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, the multipliers are:

Short Wave: $1000/22.0\ \mu V/(W\ m^{-2}) = 45.46\ (W\ m^{-2})/mV$

Long Wave: $1000/11.6\ \mu V/(W\ m^{-2}) = 86.21\ (W\ m^{-2})/mV$

6.2 Example Programs

6.2.1 Example Program for CR1000 Datalogger

```
'CNR2 Net Radiometer program for CR1000 datalogger

'*** Wiring ***

'1H    Short wave signal  (white)
'1L    Short wave signal reference (blue)
'2H    Long wave signal  (brown)
'2L    Long wave signal reference (black)
'gnd   Shield (clear)

'Declare Constants
Const CNR2_SW_CAL = 45.46      'Unique multiplier for CNR 2 net SW radiation (1000/sensitivity).
Const CNR2_LW_CAL = 86.21      'Unique multiplier for CNR 2 net LW radiation (1000/sensitivity).

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

'Define Data Tables

DataTable(Table1,True,-1)
    DataInterval(0,60,Min,10)
    Minimum(1,Net_Shortwave,IEEE4,False,True)
    Maximum(1,Net_Shortwave, IEEE4,False,True)
    Average(1,Net_Shortwave, IEEE4,False)
```

```
      Minimum(1,Net_Longwave, IEEE4,False,True)
      Maximum(1,Net_Longwave, IEEE4,False,True)
      Average(1,Net_Longwave, IEEE4,False)
      Average(1,Net_Rad, IEEE4,False)
EndTable

'Main Program
BeginProg
      Scan(1,Sec,1,0)
            'CNR2 Net Radiation Measurements
            VoltDiff(Net_Shortwave,1,mV25,1,True,200,250, CNR2_SW_CAL,0.0)
            VoltDiff(Net_Longwave,1,mV25,2,True,0,250, CNR2_LW_CAL,0.0)
            Net_Rad = Net_Shortwave+Net_Longwave

            'Call Data Tables and Store Data
            CallTable(Table1)

      NextScan
EndProg
```

6.2.2 Example Program for CR10X Datalogger

```
;CNR2 Net Radiometer program for CR10X datalogger

;*** Wiring ***

; 1H   Shortwave signal  (white)
; 1L   Shortwave signal reference (blue)
; 2H   Longwave signal  (brown)
; 2L   Longwave signalreference- (black)
;gnd   Shiled (clear)

;
;*** Wiring ***

; 1H   Shortwave signal (white)
; 1L   Shortwave signal reference (blue)
;gnd
; 2H   Longwave signal (brown)
; 2L   Longwave signal reference (black)
;gnd   Shield (clear)

;
*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:    45.46           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:   86.21          Multiplier
   6:   0.0            Offset

;
;Measure Net Radiation
3:  Z=X+Y (P33)
   1:   1              X Loc [ Net_SW    ]
   2:   2              Y Loc [ Net_LW    ]
   3:   3              Z Loc [ Net_Rad   ]

;Output data to the final storage every 60 minutes
;
4:  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)

5:  Set Active Storage Area (P80)^2826
   1:   1              Final Storage Area 1
   2:   102            Array ID

6:  Real Time (P77)^11314
   1:   1220           Year,Day,Hour/Minute (midnight = 2400)

7:  Minimum (P74)^13722
   1:   1              Reps
   2:   10             Value with Hr-Min
   3:   1              Loc [ Net_SW    ]

8:  Maximum (P73)^10217
   1:   1              Reps
   2:   10             Value with Hr-Min
   3:   1              Loc [ Net_SW    ]

9:  Average (P71)^10475
   1:   1              Reps
   2:   1              Loc [ Net_SW    ]

10:  Minimum (P74)^11228
   1:   1              Reps
   2:   10             Value with Hr-Min
   3:   2              Loc [ Net_LW    ]

11:  Maximum (P73)^17442
   1:   1              Reps
   2:   10             Value with Hr-Min
   3:   2              Loc [ Net_LW    ]
```

```
12:  Average (P71)^29073
   1:    1                  Reps
   2:    2                  Loc [ Net_LW    ]

13:  Average (P71)^15174
   1:    1                  Reps
   2:    3                  Loc [ Net_Rad   ]

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

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

*Table 3 Subroutines

End Program
```

7. Calibration

Recalibrate the CNR2 every two years, or as an alternative, by running a higher standard next to it. Compare the pyranometers over a two-day period when the days are clear. Compare the pyrgeometers during the night. Deviations of more than 6% can be used to correct the calibration factors.

8. Maintenance

Clean domes and windows with distilled water or alcohol. Readings are reduced if domes and/or windows are not clean.

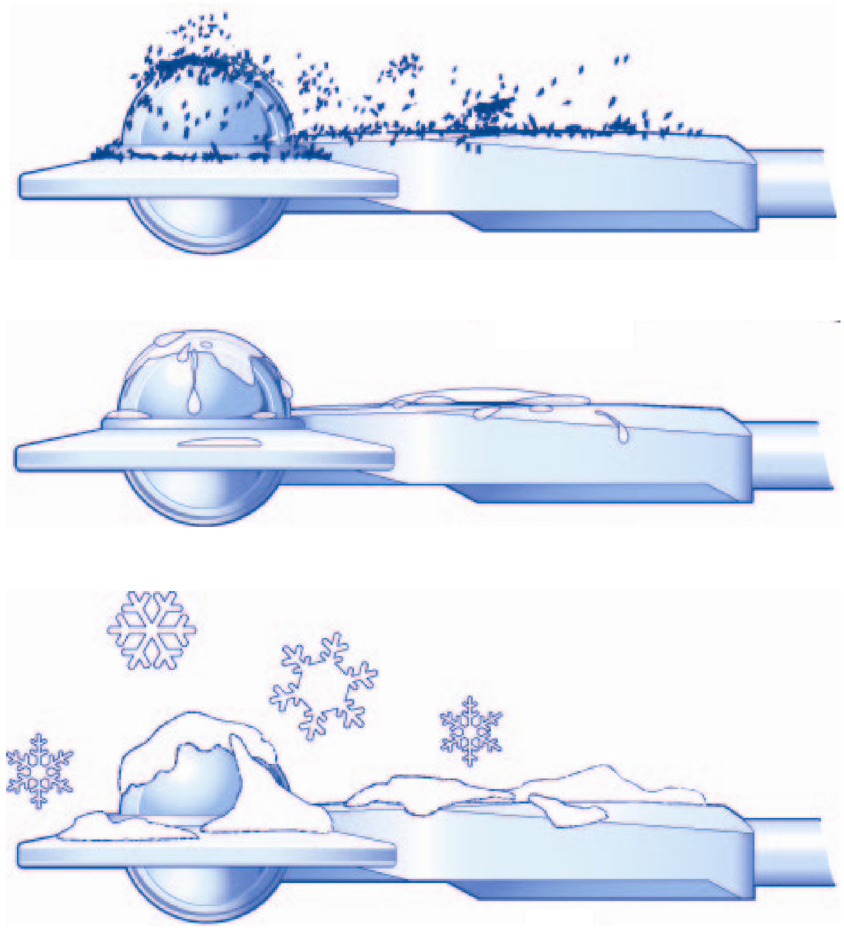

FIGURE 8-1. Dirt, Rain or Snow on CNR2 Sensors will Reduce the Readings

Keep instrument leveled at all times during the measurements.

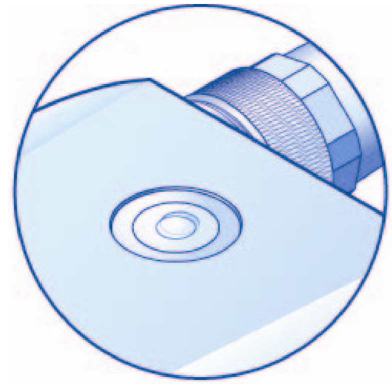

FIGURE 8-2. CNR2 Net Radiometer Bubble-Level

Replace drying cartridge every 6 months.

FIGURE 8-3. Replacing Drying Cartridge
(first replacement cartridge comes with the 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

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