



**KIPP &  
ZONEN**  
SINCE 1830



**CNR 4**  
Net Radiometer

# Instruction Manual



## **IMPORTANT USER INFORMATION**

**Reading this entire manual is recommended for full understanding of the use of this product.**

The exclamation mark within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance instructions in the literature accompanying the instrument.

Should you have any comments on this manual we will be pleased to receive them at:

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## DECLARATION OF CONFORMITY

According to EC guideline 89/336/EEC 73/23/EEC

We: Kipp & Zonen B.V.  
Delftechpark 36  
2628 XH Delft  
The Netherlands

Declare under our sole responsibility that the product

Type: CNR 4  
Name: Net Radiometer

And

Type: CNF 4  
Name: Ventilation Unit

To which this declaration relates is in conformity with the following standards

Imissions EN 50082-1 Group standard

Emissions EN 50081-1 Group standard  
EN 55022

Safety standard IEC 1010-1

Following the provisions of the directive



Dr. Foeke Kuik  
CEO  
Kipp & Zonen B.V.

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## 1 GENERAL INFORMATION

The CNR 4 is a 4 component net radiometer that measures the energy balance between incoming short-wave and long-wave Far Infrared (FIR) radiation versus surface-reflected short-wave and outgoing long-wave radiation.

The CNR 4 net radiometer consists of a pyranometer pair, one facing upward, the other facing downward, and a pyrgeometer pair in a similar configuration. The pyranometer pair measures the short-wave radiation. And the pyrgeometer pair measures long-wave radiation. The upper long-wave detector of CNR 4 has a meniscus dome. This ensures that water droplets roll off easily and improves the field of view to nearly 180°, compared with a 150° for a flat window. All 4 sensors are integrated directly into the instrument body, instead of separate modules mounted onto the housing. Each sensor is calibrated individually for optimal accuracy.

Two temperature sensors, a Pt-100 and Thermistor, are integrated for compatibility with every data logger. The temperature sensor is used to provide information to correct the infrared readings for the temperature of the instrument housing. Care has been taken to place the long-wave sensors close to each other and close to the temperature sensors. This assures that the temperatures of the measurement surfaces are the same and accurately known. This improves the quality of the long-wave measurements.

The design is very light in weight and has an integrated sun shield that reduces thermal effects on both long-wave and short-wave measurements. The cables are yellow with waterproof connectors as used with all our new radiometers. The mounting rod can be unscrewed for transport, like the CNR 2.

An optional ventilation unit with heater is designed as an extension of the sunshield and can be fitted new to the CNR 4 or retro-fitted later. The ventilation unit CNF 4 is compact and provides efficient air-flow over the domes and windows to minimize the formation of dew and reduce the frequency of cleaning. The integrated heater can be used to melt frost.

The CNR 4 specifications when used with CNF 4 comply with the WMO classification of Good Quality

The Net Radiometer, CNR 4, 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 CNR 4 design is such that both the upward facing and the downward-facing instruments measure the energy that is received from the whole hemisphere (180 degrees field of view). The output is expressed in Watts per square meter. The total spectral range that is measured is roughly from 0.3 to 42 micrometers. This spectral range covers both the Solar Radiation, 0.3 to 3 micrometers, and the Far Infrared radiation, 4.5 to 42 micrometers.

Chapter 1 describes how to operate the CNR 4, giving separate attention to the use of the individual pyranometers and pyrgeometers. More about the physics of the pyranometer and pyrgeometer can be found in chapter 2.

The CNR 4 radiometers all have individual calibration factors. As opposed to the CNR 1 they are not made equal. The advantage is that the individual sensitivities are more accurate than when made equal with shunt and series resistors.

For quality assurance of the measurement data, we recommend the recalibration of the CNR 4 as part of a regular maintenance schedule every two years. More about calibration can be found in chapter 3.

The CNR 4 is intended for continuous outdoor use. It is weatherproof. The materials used in Pyranometer and pyrgeometer are robust. Contrary to most competitive instruments, plastic domes are not used. Therefore the CNR 4 requires very low maintenance. For optimal results however, proper care must be taken. More about maintenance can be found in chapter 4. Chapter 5 can be consulted if a problem with the CNR 4 is suspected; this chapter addresses trouble shooting.

The general user should read chapter 1 and chapter 4.

## 1.1 Connecting the CNR 4

### 1.1.1 The difference between temperature and sensor connection

CNR 4 has several output signals: two voltages for the pyranometers, two voltages for the pyrgeometers, and two temperature sensors as standard: a 4 wire Pt-100 connection and a 2 wire connection for the 10k thermistor. Depending on the used data logger one of the temperature sensors can be used.

The connector with the 4 sensor outputs is indicated with an S on the back of the CNR 4, the temperature connector is indicated with a T. The sensor connector has 8 pins and 8 wires are coming out of the cable on the other end. The Temperature connector has also 8 pins but only 6 wires are coming out of the cable.

Exchanging the connectors will not damage the CNR 4. To prevent mix up of the cables after installation it is advised to mark the cables with a permanent marker or tape showing also S and T.

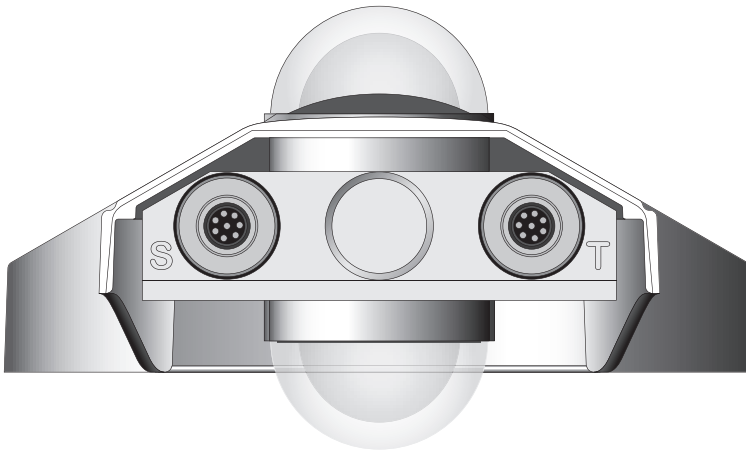




Figure 1.1 Back of the CNR 4 with the connector for sensor outputs on the left, the temperature connector on the right and mounting rod in the middle.

### 1.1.2 The radiometer Sensor connector (S)

CNR 4 sensor connector carries the signals for the two pyranometers and two pyrgeometers. The pin numbers and wire colours are indicated in the diagram below. The shield of the cable is twisted together and covered with a black sleeve. If the CNR 4 (rod) is grounded to the mast it is advised not to connect the shielding on the data logger side. This might cause ground loops and offsets in the signal.



<b>CNR 4 NET RADIOMETER • SENSOR</b>		
8 WIRE CABLE • 8-ADRIGES KABEL • CÂBLE 8 FILS • CABLE DE 8 CONDUCTORES		
Wire Kabel Fil Cable	Function Funktion Fonction Función	Connect with Anschluss an Relier à Conectar con
<b>1</b> Red Rot • Rouge • Rojo	+	Pyranometer Upper Oben • Supérieur • Superior
<b>2</b> Blue Blau • Bleu • Azul	-	
<b>7</b> White Weiss • Blanc • Blanco	+	Pyranometer Lower Unten • Inférieur • Más bajo
<b>8</b> Black Schwarz • Noir • Negro	-	
<b>5</b> Grey Grau • Gris • Gris	+	Pyrgeometer Upper Oben • Supérieur • Superior
<b>4</b> Yellow Gelb • Jaune • Amarillo	-	
<b>6</b> Brown Braun • Brun • Marrón	+	Pyrgeometer Lower Unten • Inférieur • Más bajo
<b>3</b> Green Grün • Vert • Verde	-	
 Shield Abschirmung Protection Malla	Housing Gehäuse Boîte Cubierta	 Ground * Erde Terre Tierra

\* Connect to ground if radiometer not grounded  
 Mit Erde verbinden, wenn das Radiometer nicht geerdet ist  
 Reliez à la terre si le radiomètre n'est pas connecté  
 Conectar a tierra si el radiómetro no lo está

Figure 1.2 The sensor connections of the CNR 4. The sensor has four mV outputs, 2 for the pyranometers and 2 for the pyrgeometers

### 1.1.3 The radiometer Temperature connector (T)

The temperature connector of the CNR 4 carries the signals for the PT-100 and Thermistor. The PT-100 and Thermistor have identical accuracy, the reason for selecting one or the other is mainly the data logger involved. The Pt-100 temperature sensor has 4 wires, two for the measuring current and two for measuring the voltage over the resistor (100 Ohm @ 0 °C) . In this way the measurement accuracy is minimally affected by the cable length. The thermistor has a higher impedance of 10 kOhm and is therefore less influenced by cable length but has no compensation for it. The shield of the cable is twisted together and covered with a black sleeve. If the CNR 4 (rod) is grounded to the mast it is advised not to connect the shielding on the data logger side. This might cause ground loops and offsets in the signal.






CNR 4 NET RADIOMETER • TEMPERATURE				
6 WIRE CABLE • 6-ADRIGES KABEL • CÂBLE 6 FILS • CABLE DE 6 CONDUCTORES				
7		White Weiss • Blanc • Blanco	Thermistor	Standard Standard Etalon Estándar
		Black Schwarz • Noir • Negro		
5		Grey Grau • Gris • Gris	Combined Kombiniert Combiné Combinado	Pt-100 Standard Etalon Estándar
3		Green Grün • Vert • Verde		
4		Yellow Gelb • Jaune • Amarillo	Combined Kombiniert Combiné Combinado	
6		Brown Braun • Brun • Marrón		
		Shield Abschirmung Protection Malla	Housing Gehäuse Boîte Cubierta	Ground * Erde Terre Tierra

Figure 1.3 The temperature connections of the CNR 4. The instrument has one (4-wire) Pt-100 output and a Thermistor with a 2-wire connection.



### 1.1.4 The (optional) CNF 4 connector

The optional ventilator CNF 4 for the CNR 1 has separate wires for heating and ventilation. In case the heater is used also the ventilator should be active. The other way around the ventilator can be used without heating. When the ventilation unit is mounted later on the CNR 4, the extra bottom plate mounts to the bottom of the CNR 4. The (S) and (T) cables run on both sides of the ventilator to the back of the CNF 4 housing. The extra cover that comes with the CNF 4 slides under the CNR 4 cover. The 4 pins connector on the back of the CNF 4 is shown below. The CNR 4 without CNF 4 is supplied with an extra serial number label. This can be used to put on the bottom of the CNF 4 when mounted (later) on the CNR 4.





CNF 4 VENTILATION UNIT (OPTIONAL • OPTION • OPTION • OPCIONAL)			
4 WIRE CABLE • 4-ADRIGES KABEL • CÂBLE 4 FILS • CABLE DE 4 CONDUCTORES			
Wire Kabel Fil Cable	Function Funktion Fonction Función	Connect with Anschluss an Relier à Conectar con	
<b>1</b> Red Rot • Rouge • Rojo	+	5 Watt ventilator Ventilator • Ventilateur • Ventilador	12 VDC
<b>2</b> Blue Blau • Bleu • Azul	-		
<b>3</b> Green Grün • Vert • Verde	+	10 Watt heater Heizung • Chauffage • Calentador	12 VDC
<b>4</b> Yellow Gelb • Jaune • Amarillo	-		
 Shield Abschirmung Protection Malla		Housing Gehäuse Boîte Cubierta	 Ground * Erde Terre Tierra

Figure 1.3 The heater and ventilator connections of the CNF 4.

### 1.1.5 Using the CNR 4 calibration factors

The pyranometer generates a mV signal that is simply proportional to the incoming solar Radiation. The conversion factor between voltage, V, and Watts per square metre of solar irradiance E, is the so-called calibration constant C (or sensitivity).

$$\text{For each pyranometer} \quad E = V/C \quad (1.1)$$

When using the pyrgeometer, you should realise that the signal that is generated by the pyrgeometer represents the exchange of Far Infrared (thermal) radiation between the pyrgeometer and the object that it is facing. This implies that the pyrgeometer will generate a positive voltage output, V, when it faces an object that is hotter than its own sensor housing, and that it will give a negative voltage signal when it faces an object that is colder. This means that for estimating the Far Infrared radiation that is generated by the object that is faced by the pyrgeometer, usually the sky or the soil, you will have to take the pyrgeometer temperature, T, into account. This is why the temperature sensors are incorporated in the CNR 4's body near the pyrgeometer sensing element, and has therefore the same temperature as the pyrgeometer sensor surface. The calculation of the Far Infrared irradiance, E, is done according to the following equation:

$$\text{For the pyrgeometer only} \quad E = V/C + 5.67 \cdot 10^{-8} \cdot T^4 \quad (1.2)$$

In this equation C is the sensitivity of the sensor. Please bear in mind that T is in Kelvin, and not in Celsius or Fahrenheit.

### 1.1.6 Using the CNR 4 measuring Net Radiation

In the CNR 4 all components are measured separately. This implies that you should connect all individual radiometers and one of the temperature sensors. The two pyranometers will measure the solar radiation, both incoming and reflected, the two pyrgeometers will measure the Far Infrared radiation. For proper analysis of the pyrgeometer measurement results, they must be temperature corrected using the temperature measurement. The following paragraphs describe how you should treat the instrument, and how different parameters like net Solar radiation, net Far Infrared radiation, soil temperature, sky temperature, and Net (total) radiation can be calculated. Because all radiometers have different sensitivities it is not possible to interconnect the outputs to get the total Net Radiation.

#### 1.1.6.1 Measuring Solar radiation with the pyranometer

Measuring with a pyranometer can be done by connecting two pyranometer wires, + and -, to a voltmeter. Incidental light results in a positive signal. The pyranometer mounting plate and ambient air should be at the same temperature, as much as possible. Conversion of the voltage to irradiance can be done according to equation 1.1. This is sometimes done in the data logging system itself, sometimes during evaluation in the user's software. Measuring with the upward-facing pyranometer, the so-called global (solar) radiation is measured. The downward-facing pyranometer measures the reflected solar radiation. When calculating the Net radiation, the Reflected radiation must be subtracted from the global radiation. See 1.1.6.5.

#### 1.1.6.2 Measuring Far Infrared radiation with the pyrgeometer

A measurement with the pyrgeometer can be performed by connecting two pyrgeometer wires, + and -, to a voltmeter. A signal radiating from a source which is warmer than the pyrgeometer results in a positive signal.

To measure the Far Infrared irradiances with the two pyrgeometers, separately the Pt-100 output is required. The formula 1.2 is used to calculate the Far Infrared irradiance of the sky and of the ground.

With the downward-facing pyrgeometer, you would generally measure the Far Infrared radiation that is emitted by the ground. In contrast, the upward-facing pyrgeometer is generally used to measure the Far Infrared radiation from the sky. As the sky is typically colder than the instrument, you can expect negative voltage signals from the upward-facing pyrgeometer.

#### 1.1.6.3 Measuring the CNR 4's body temperature

The CNR 4 has two temperature sensors built in as standard. The main reason to choose between the Pt-100 or the Thermistor is the connected data logger.

Some data loggers have inputs for thermistors some only for thermistors some have both.

Check carefully the correct sensor regarding to the data logger. There is no difference in accuracy.

The Pt-100 however can be used in 4 wire mode as is therefore compensated for longer wires.

The Thermistor has itself higher impedance (10k) and is less susceptible for longer wires, but can not be compensated for it.

To obtain a signal from the Pt-100, a current of about 1 mA is fed through two wires on either side of the PT-100. The voltage that is generated must be measured using the other pair of wires which are connected in parallel with the PT-100. This is known as a 4-wire measurement. Measuring in this manner eliminates errors during measurement, which would be produced by additional wire length. Some systems have a 3-wire connection. In this case omit one current lead and follow the instructions of your measurement system manual. Table 1.1 states the Pt-100 resistance values as a function of temperature. Please note that for use in formula 1.2, you must use Kelvin, not degrees Celsius or Fahrenheit. Most data acquisition systems have standard readout and conversion for Pt-100's. The thermistor resistance values as a function of temperature are indicated in table 1.2.

Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]
-30	88.22	0	100.00	30	111.67
-29	88.62	1	100.39	31	112.06
-28	89.01	2	100.78	32	112.45
-27	89.40	3	101.17	33	112.83
-26	89.80	4	101.56	34	113.22
-25	90.19	5	101.95	35	113.61
-24	90.59	6	102.34	36	113.99
-23	90.98	7	102.73	37	114.38
-22	91.37	8	103.12	38	114.77
-21	91.77	9	103.51	39	115.15
-20	92.16	10	103.90	40	115.54
-19	92.55	11	104.29	41	115.93
-18	92.95	12	104.68	42	116.31
-17	93.34	13	105.07	43	116.70
-16	93.73	14	105.46	44	117.08
-15	94.12	15	105.85	45	117.47
-14	94.52	16	106.24	46	117.85
-13	94.91	17	106.63	47	118.24
-12	95.30	18	107.02	48	118.62
-11	95.69	19	107.40	49	119.01
-10	96.09	20	107.79	50	119.40
-9	96.48	21	108.18	51	119.78
-8	96.87	22	108.57	52	120.16
-7	97.26	23	108.96	53	120.55
-6	97.65	24	109.35	54	120.93
-5	98.04	25	109.73	55	121.32
-4	98.44	26	110.12	56	121.70
-3	98.83	27	110.51	57	122.09
-2	99.22	28	110.90	58	122.47
-1	99.61	29	111.28	59	122.86

Table 1.1 Resistance values versus temperature in °C of the CNR 4's Pt-100.  
The Pt-100 complies with the class A specifications of DIN.

Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]
-30	135200	0	29490	30	8194
-29	127900	1	28150	31	7880
-28	121100	2	26890	32	7579
-27	114600	3	25690	33	7291
-26	108600	4	24550	34	7016
-25	102900	5	23460	35	6752
-24	97490	6	22430	36	6500
-23	92430	7	21450	37	6258
-22	87660	8	20520	38	6026
-21	83160	9	19630	39	5805
-20	78910	10	18790	40	5592
-19	74910	11	17980	41	5389
-18	71130	12	17220	42	5193
-17	67570	13	16490	43	5006
-16	64200	14	15790	44	4827
-15	61020	15	15130	45	4655
-14	58010	16	14500	46	4489
-13	55170	17	13900	47	4331
-12	52480	18	13330	48	4179
-11	49940	19	12790	49	4033
-10	47540	20	12260	50	3893
-9	45270	21	11770	51	3758
-8	43110	22	11290	52	3629
-7	41070	23	10840	53	3504
-6	39140	24	10410	54	3385
-5	37310	25	10000	55	3270
-4	35570	26	9605	56	3160
-3	33930	27	9227	57	3054
-2	32370	28	8867	58	2952
-1	30890	29	8523	59	2854

Table 1.2 Resistance values versus temperature in °C of the CNR 4's thermistor.

Relatively small errors occur when the CNR 4 is not in thermal equilibrium. This happens for example when the heater is on, or when the sun is shining. When the heater and ventilator are on, the largest expected deviation between real sensor temperature and Pt-100 or thermistor reading is less than 0.5 degree.

The internal temperature sensors will not give a good indication of ambient air temperature; at 1000 Watts per square meter Solar Radiation, and no wind, the instrument temperature can rise a few degrees above ambient temperature. This will not affect the readings of the CNR 4

The offsets of both pyranometers and pyrgeometers might be larger than 5 Watts per square meter if large temperature gradients are forced on the instrument (larger than 5 K/hr). This happens for example when rain hits the instrument. The occurrence of this can be detected using the temperature sensor readout. It can be used as a tool for quality assurance of your data.

#### 1.1.6.4 Calculation of the albedo for solar radiation

The albedo is the ratio of incoming and reflected Solar radiation. It is a figure somewhere between 0 and 1. Typical values are 0.9 for snow, and 0.3 for grassland. To determine albedo, the measured values of the two pyranometers can be used. The pyrgeometers are not involved, as they do not measure Solar radiation. Do not use measured values when solar elevation is lower than 10 degrees above the horizon. Errors in measurement at these elevations are likely and thus yielding unreliable results. This is due to deviations in the directional response of the pyranometers.

$$\text{Albedo} = (E \text{ lower pyranometer}) / (E \text{ upper pyranometer}) \quad (1.3)$$

In the above formula, E is calculated according to formula 1.1.

Albedo will always be smaller than 1. Checking this can be used as a tool for quality assurance of your data. If you know the approximate albedo at your site, the calculation of albedo can also serve as a tool for quality control of your measured data at this specific site.

#### 1.1.6.5 Calculation of the Net Solar radiation

Net Solar radiation is the incoming Solar Radiation minus the reflected solar radiation. It equals the solar radiation that is absorbed by the earth's surface.

$$\text{Net Solar radiation} = (E \text{ upper pyranometer}) - (E \text{ lower pyranometer}) \quad (1.4)$$

In this formula E is calculated according to formula 1.1.

Net Solar radiation will always be positive. Checking this can be used as a tool for quality assurance of your measured data.

#### Calculation of the Net Far Infrared radiation, soils temperature and sky temperature

Net Far Infrared radiation is, like Net Solar radiation, the part that contributes to heating or cooling of the earth's surface. In practice most of the time, Net Far Infrared radiation will be negative.

$$\text{Net Far Infrared radiation} = (E \text{ upper pyrgeometer}) - (E \text{ lower pyrgeometer}) \quad (1.5)$$

In this formula E is calculated according to formula 1.2. From this equation the term with T cancels.

The E measured with the pyrgeometer, actually represents the irradiance of the sky (for the upward-facing pyrgeometer) or the ground (for the downward-facing pyrgeometer). Assuming that these two, ground and sky, behave like perfect blackbodies (actually this is only in theory), you can calculate an effective "Sky temperature" and an effective "Ground temperature".

$$\text{Sky temperature} = ((E \text{ upper pyrgeometer}) / 5.67 \cdot 10^{-8})^{1/4} \quad (1.6)$$

$$\text{Ground temperature} = ((E \text{ lower pyrgeometer}) / 5.67 \cdot 10^{-8})^{1/4} \quad (1.7)$$

As a rule of thumb, for ambient temperatures of about 20 degrees Celsius, you can say that one degree of temperature difference between two objects results in a 5 Watts per square metre exchange of radiative energy (infinite objects):

1 degree of temperature difference = 5 Watts per square metre (rule of thumb)

1.1.6.6 Calculation of the Net (total) radiation

The Net radiation, NR, can be calculated using all 4 sensor measurement results:

$$NR = (E \text{ upper pyranometer}) + (E \text{ upper pyrgeometer}) - (E \text{ lower pyranometer}) - (E \text{ lower pyrgeometer}) \quad (1.8)$$

Where E is the irradiance that is calculated for the pyranometer according to equation 1.1, for the pyrgeometer according to equation 1.2. the terms with T cancel from this equation.

1.2 CNR 4 Performance under different conditions

Below, table 1.3, shows an indication of what you might typically expect to measure under different meteorological conditions. The first parameter is day and night. At night, the Solar radiation is zero. The second column indicates if it is cloudy or clear. A cloud acts like a blanket, absorbing part of the Solar radiation, and keeping Net Far Infrared radiation close to zero. The third parameter is ambient temperature. This is included to show that the "sky temperature" (column nine) tracks the ambient temperature. Under cloudy conditions this is logical; cloud bases will be colder than the ambient temperature at instrument level, the temperature difference depends roughly on cloud altitude.

Under clear sky conditions it is less obvious that sky temperature "adjusts" to the ambient temperature. This can roughly be attributed to the water vapour in the air, which is a major contributor to the Far Infrared radiation.

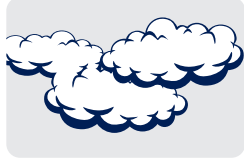

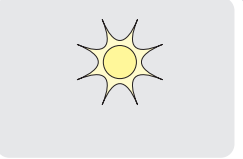
<p>Values calculated using:          Werte, errechnet aus Formel:          Calcul des valeurs à l'aide:          Utilizar valores calculados:</p> $E = \frac{U_{emf}}{S}$	 <p>Fully cloudy          Bewölkt          Très nuageux          Totalmente Nublado</p>	 <p>Sunny, partly cloudy          Sonnig, teils bewölkt          Ensoleillé, un peu nuageux          Parcialmente nublado</p>	 <p>Clear and Sunny          Klarer Himmel und sonnig          Clair et ensoleillé          Cielo despejado</p>
<b>Pyranometer</b>			
Upper Oben • Supérieur • Superior	50 ... 120 W/m <sup>2</sup>	120 ... 500 W/m <sup>2</sup>	500 ... 1000 W/m <sup>2</sup>
Lower Unten • Inférieur • Más bajo	0 ... 50 W/m <sup>2</sup>	50 ... 200 W/m <sup>2</sup>	200 ... 400 W/m <sup>2</sup>
<b>Pyrgeometer</b>			
Upper Oben • Supérieur • Superior	0 ... -10 W/m <sup>2</sup>	-10 ... -50 W/m <sup>2</sup>	-50 ... -150 W/m <sup>2</sup>
Lower Unten • Inférieur • Más bajo	-25 ... 25 W/m <sup>2</sup>	-25 ... 25 W/m <sup>2</sup>	-25 ... 25 W/m <sup>2</sup>

Fig. 1.2.1 Different measurement conditions and signals

Typical graphs for the pyrometers

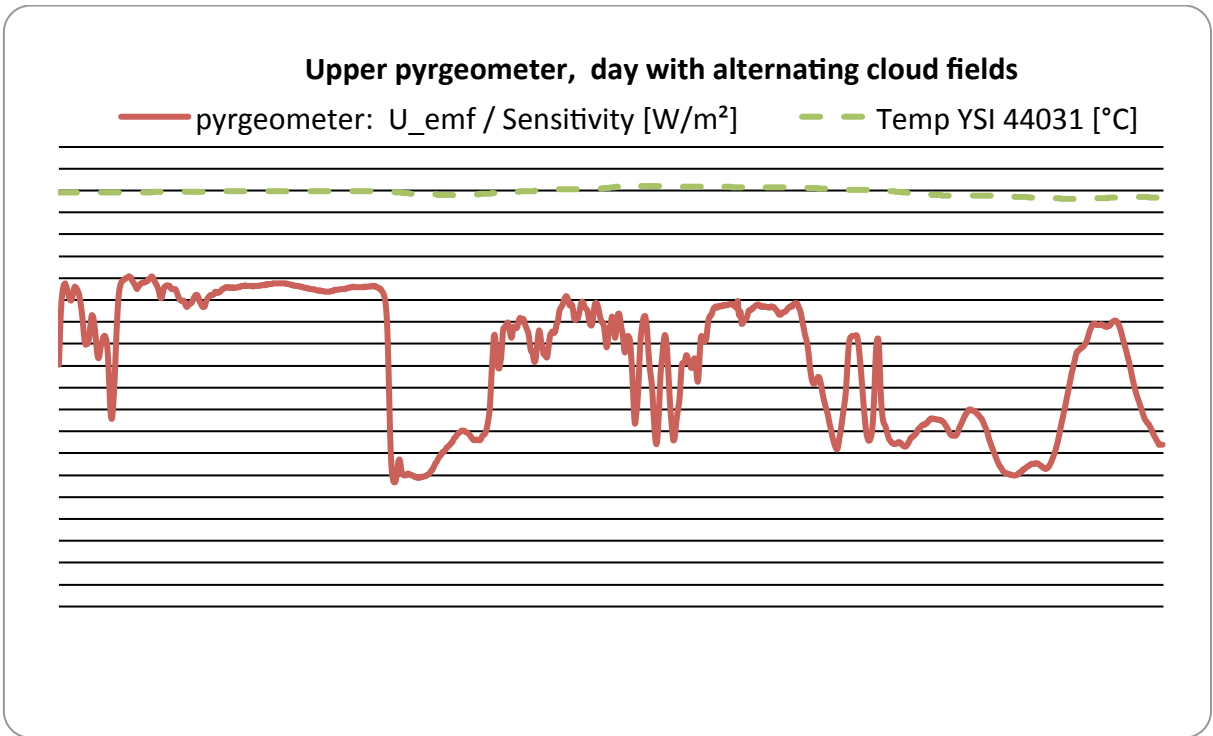


Figure 1.2.2 partly clouded day for the upper pyrometer

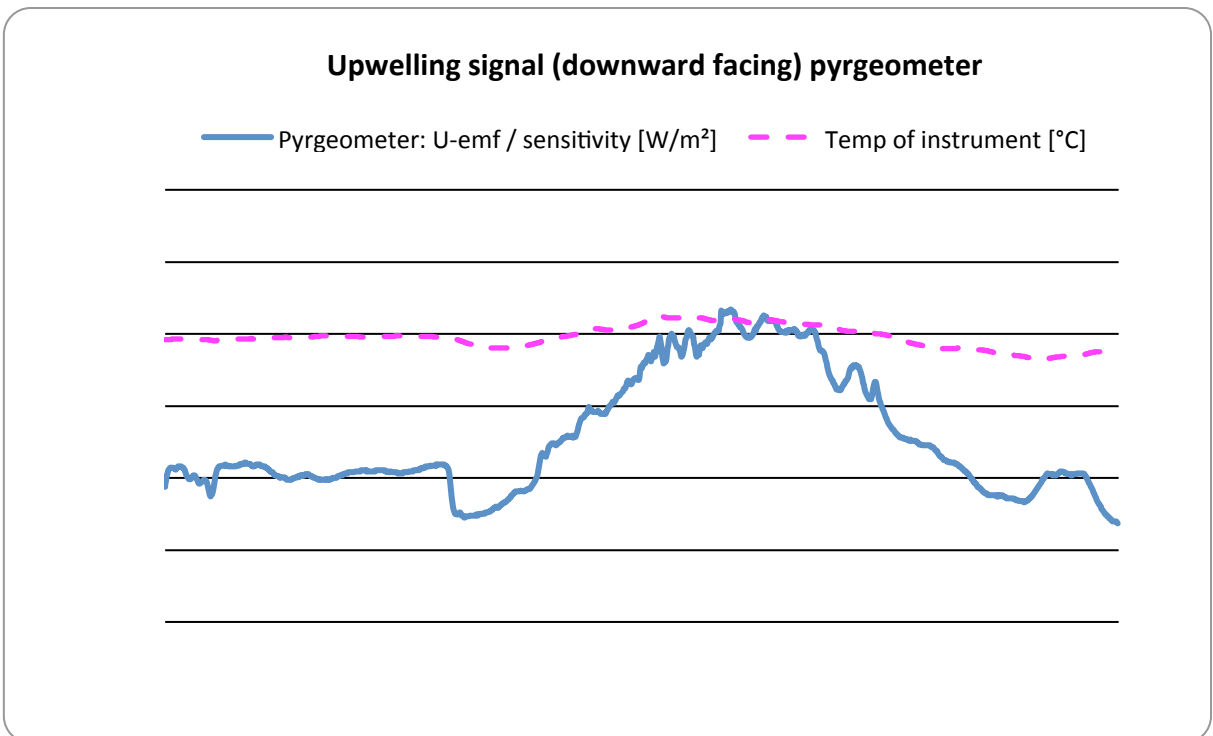


Figure 1.2.3 clear day for the downward facing pyrometer

It is assumed that when ambient temperature varies, the Net Far Infrared radiation remains roughly the same, independent of ambient temperature. The resulting measured values of the pyrgeometer's and pyranometer's are stated in columns 4 to 7. These are indicative figures only, they depend strongly on other circumstances; the pyrgeometer results, of course, change with the sensor temperature. This is indicated in column 8. During the day, the Pt-100 reading may rise due to solar heating, up to 10 degrees above ambient temperature. During the night, the sensor temperature may be lower than the ambient temperature due to Far Infrared radiative cooling. The latter two effects do not influence the end result of the calculations of Sky T and ground T. Therefore they are not taken into account in the table. Actually in column 4 you might expect to see "0 to -50" for all positions that are showing "0", in column 5 the "0" values may in reality be "-20 to +20". The resulting sky temperature is indicated in column 9. Under cloudy conditions this sky temperature is equal to ambient temperature. Under clear conditions the sky temperature is lower than the ambient temperature.

The ground temperature in column 10 is assumed to be equal to the ambient temperature. In practice it may be higher during the day, due to solar heating. Ground temperature may be lower than ambient during the night, due to Far Infrared radiative cooling. The sky and the ground temperature can be calculated from the measured values of the sensors using formulas 1.6 and 1.7.

day night	Cloudy clear	+20 °C - 20 °C	pyrgeo Up	pyrgeo low	pyrano up	pyrano low	Pt 100 thermistor	sky T	ground T
d	cloud	20	0	-20 - 20	0-500	0-150	20	20	20
d	cloud	-20	0	-20 - 20	0-500	0-150	-20	-20	-20
d	clear	20	-100*	-20 - 20	0-1300	0-400	20	1*	20
d	clear	-20	-100*	-20 - 20	0-1300	0-400	-20	-53*	-20
n	cloud	20	0	-20 - 20	0	0	20	20	20
n	cloud	-20	0	-20 - 20	0	0	-20	-20	-20
n	clear	20	-100***	-20 - 20	0**	0	20	1***	20
n	clear	-20	-100***	-20 - 20	0**	0	-20	-53***	-20

Table 1.2.2 Typical output signals of CNR 4 under different meteorological conditions. Explanation can be found in the text.

\* Values may suffer from the so-called window heating offset; the sun heats the pyrgeometer window causing a measurement error of + 10 Watts per square metre (maximum).

\*\* Values may suffer from negative Infrared offsets, caused by cooling off of the pyranometer dome by Far Infrared radiation. The maximum expected offset value is 15 Watts per square metre.

\*\*\* Values may suffer from dew deposition. This causes the pyrgeometer-up values to rise from -100 to 0 Watts per square metre.

### 1.3 Quality assurance of data

Because of the fact that separate sensors are used in the CNR 4, there are possibilities to check the quality of the data by analysing the signals. For this, you can use the measurement results of the temperature, the albedo and the net-solar radiation. If the values that are obtained for these quantities exceed certain values, this can be an indication that something is wrong. For more details we refer to the paragraphs 1.2, table 1.2.1 and 1.2.2.



## 2 CNR 4 PROPERTIES

The CNR 4 consists of two pyranometers, for measuring solar radiation, and of two pyrgeometers for measuring Far Infrared radiation. Two temperature sensors are available as standard, a Pt-100 and thermistor. The optional ventilation unit CNF 4 is described in chapter 2.5

### 2.1 Properties of the CNR 4 Net-Radiometer

The properties of CNR 4 are mainly determined by the properties of the individual sensors. Generally the accuracy of CNR 4 will be higher than that of competitive Net-Radiometers. The main reasons are that the solar radiation measurement performed by the pyranometer is accurate, and offers a traceable calibration. Also the optionally integrated ventilation and heating improve the accuracy significantly. Due to the fact that the Net Solar radiation can be very intense, 1000 Watts per square metre compared to a typical -100 for the Net Far Infrared radiation, the accuracy of the solar measurement is very critical. Wind corrections, as applied by less accurate competitive instruments are not necessary. The robustness of the materials used implies that CNR 4 will not suffer from damage inflicted by birds. Figure 2.1 depicts a drawing of CNR 4. From a spectral point of view, the pyranometer and pyrgeometer are complementary. Together they cover the full spectral range: The pyranometer from 0.3 to 3 microns, and the pyrgeometer from 4.5 to 42 microns. The gap between these two produces negligible errors.

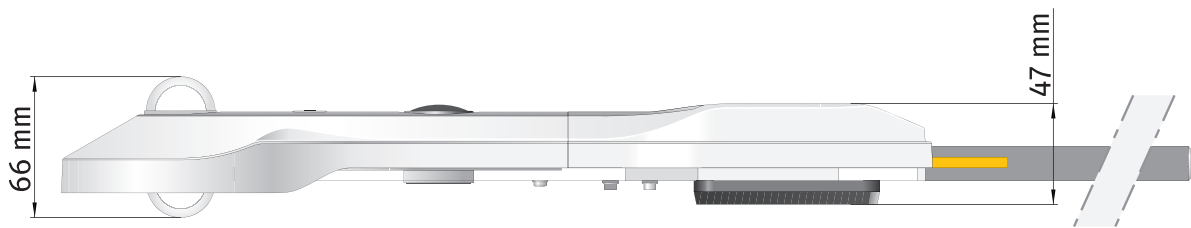


Figure 2.1 The dimensions of the CNR 4 with CNF 4 ventilation unit, side view

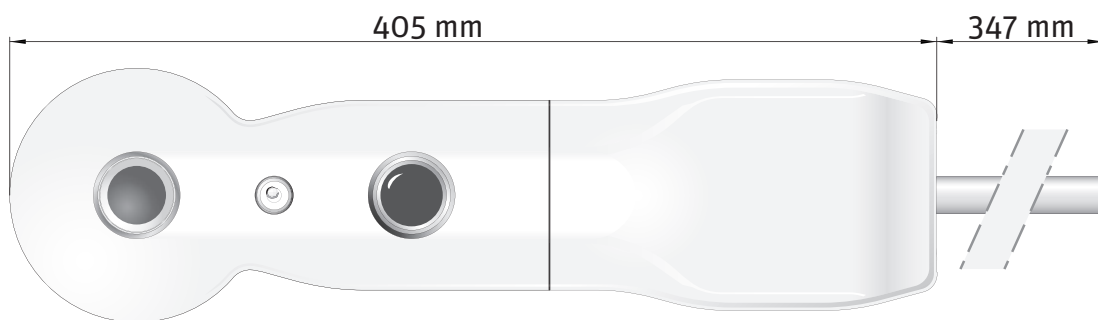


Figure 2.2 The dimensions of the CNR 4 with CNF 4 ventilation unit, top view

### 2.1.1 Specifications of the CNR 4

<b>General specifications</b>		
Environmental		<b>0 - 100% RH (Relative Humidity)</b>
<b>Definition</b>		<i>Intended for continuous outdoor use</i>
Bubble level sensitivity		< 0.5° (bubble half inside ring)
<b>General Construction</b>		
Sensor		<b>Thermopile</b>
Receiver paint		<b>Carbon Black</b>
Desiccant		<b>Silica gel</b> (replaceable)
Housing materials		<b>Anodized Aluminum body</b>
Cable Connectors		Binder series 712
Cable (2 cables)		Color Yellow, Poly Urethane, Halogen free, UV blocking
Cable length (2 cables)	m	10 (standard), 25, 50 (optional)
Weight	kg	0.85 (without cables)
Shock / vibration		IEC 721-3-2-2m2
Operating temperature	°C	-40 to +80
CE		according to EC guideline 89/336/EEC 73/23/EEC
Environmental protection		IP 67

## 2.2 Properties of the pyranometer

The pyranometer consists of a thermopile sensor and a glass dome both integrated in the CNR 4 body. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation, and converts it to heat. The resulting heat flow causes a temperature difference across the thermopile. The thermopile generates a voltage output. The thermopile and the resistor determine most electrical specifications. The absorber paint and the dome determine spectral specifications. The thermopile is encapsulated in the housing in such a way that its field of view is 180 degrees, and that its angular characteristics fulfil the so-called cosine response.

### 2.2.1 Specifications of the pyranometer

Pyranometers Specification	Unit	Value (All indicated values are absolute values)
Spectral range	nm	300 - 2800 (50% points)
Definition		Instrument sensitivity within a specific spectral range
Sensitivity	$\mu\text{V}/\text{W}/\text{m}^2$	10 to 20
Definition		Calibration factor
Impedance	$\Omega$	20 to 200, typically 50
Definition		<i>Typical resistance measured at the output</i>
Response time	s	< 18 (95% response)
Definition		<i>Sensor response time</i>
Non-linearity	%	< 1 (from 0 to 1000 $\text{W}/\text{m}^2$ irradiance)
Definition		<i>Maximum deviation from the responsivity at 500 <math>\text{W}/\text{m}^2</math> due to any change of irradiance within the indicated range.</i>
Temperature dependence of sensitivity	%	N/S (-40 °C to -10 °C) < 4 (-10 °C to +40 °C) N/S (+40 °C to +80 °C)
Definition		<i>Maximum error due to any change of instrument temperature within the indicated temperature interval.</i>
Tilt error	%	< 1
Definition		<i>Maximum deviation from the responsivity when tilted at any angle and at 1000 <math>\text{W}/\text{m}^2</math> irradiance .</i>
Zero offset A	$\text{W}/\text{m}^2$	< 15 (0 to -200 $\text{W}/\text{m}^2$ / IR net irradiance)
Definition		<i>Caused by cooling of the dome due to sky radiation</i>
Zero offset B	$\text{W}/\text{m}^2$	< 3 (at 5 K/h temp. change) < 1 (with CVF 4 installed)
Definition		<i>Response to change in ambient temperature.</i>
Field of view: Upper detector Lower detector		180° 150° (due to lower sun shield. To prevent illumination at low zenith angles)
Definition		<i>Sensor opening angle</i>
Directional error	$\text{W}/\text{m}^2$	< 20 (angles up to 80° with 1000 $\text{W}/\text{m}^2$ beam radiation)
Definition		<i>Combined zenith and azimuth error from 0°- 80° with 1000 <math>\text{W}/\text{m}^2</math> beam radiation</i>

Irradiance:	W/m <sup>2</sup>	0 to 2000
Definition		<i>Measurement range</i>
Non-stability	%	< 1
Definition		<i>Maximum change of sensitivity per year, percentage of full scale</i>
Spectral selectivity	%	< 3% (350 - 1500 nm spectral interval)
Definition		<i>Deviation of the product of spectral absorption and spectral transmittance from the corresponding mean within the indicated spectral range</i>
Uncertainty in daily total	%	< 5 (95 % confidence level)
Definition		<i>Achievable uncertainty</i>
<b>International standards</b>		
WMO ISO		Good quality First Class
Instrument calibration		Indoors, side by side against reference CMP 3 pyranometer according to ISO 9847:1992 annex A.3.1

### 2.2.2 Spectral properties of the pyranometer

The spectral properties of the pyranometer are mainly determined by the properties of the absorber paint and the glass dome. These are depicted in figure 2.3

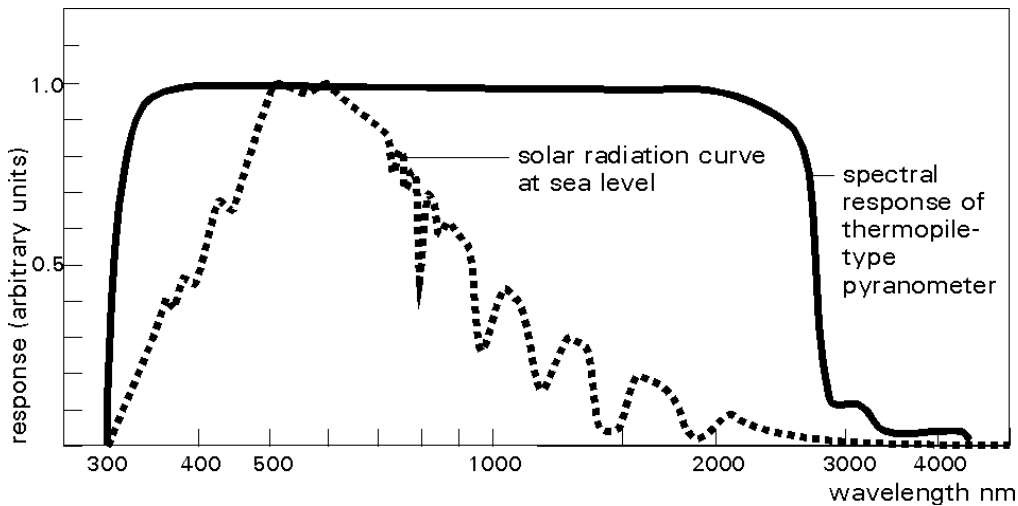


Figure 2.3 The spectral sensitivity of the pyranometer in combination with the spectrum of the sun, under a clear sky.

### 2.2.3 Directional / Cosine response of the pyranometer

The measurement of solar radiation falling on a surface (also called irradiance or radiative flux) requires three assumptions: The surface is spectrally black, i.e. that it absorbs all radiation from all wavelengths. Its field of view is 180 degrees. The directional properties are similar to that of a blackbody. Another way of expressing these directional properties is to say that the sensor has to comply with the cosine response.

A perfect cosine response will show maximum sensitivity (1) at an angle of incidence of 0E (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90E (radiation passing over the sensor surface). Between 90 and 0 degrees, the sensitivity should be proportional to the cosine of the angle of incidence. Figure 2.4 shows the behaviour of a typical pyranometer. The vertical axis shows the deviation from ideal behaviour, expressed in percentage of the ideal value.

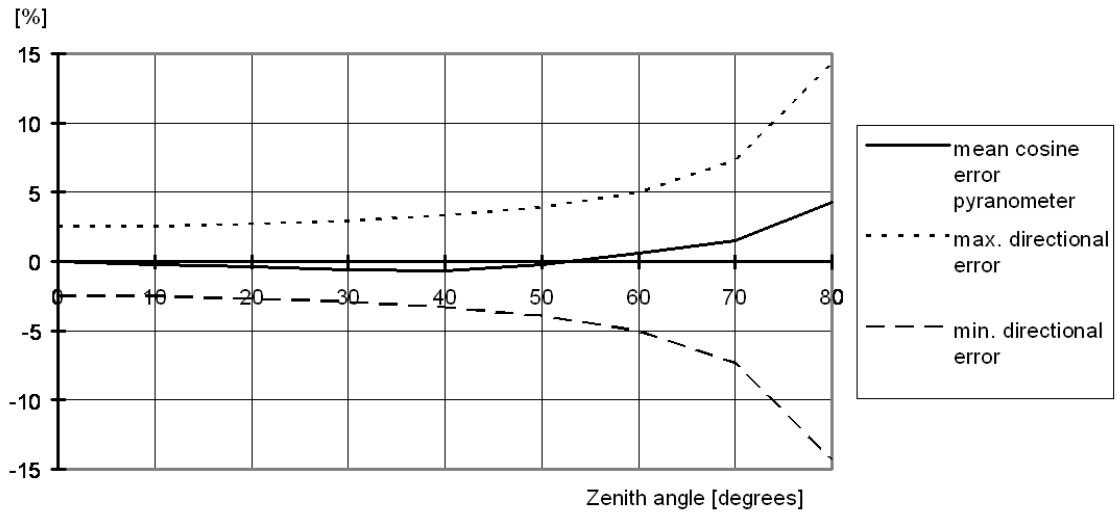


Figure 2.4 The directional response, or cosine response, of the pyranometer:  
 On the horizontal axis, the zenith angle is shown (0E zenith angle equals 90E angle of incidence).  
 The vertical axis shows the deviation from the ideal cosine behaviour expressed in percents.

### 2.3 Properties of the pyrgeometer

The pyrgeometer consists of a thermopile sensor and a silicon window integrated in the CNR 4 body. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation and converts it to heat. The resulting heat flow is converted to a voltage by the thermopile. Most electrical specifications are determined by the thermopile and the resistor.

Spectral specifications are determined by the absorber paint and the window. The window serves both as environmental protection and as a filter. It only transmits the relevant Far Infrared radiation, while obstructing the Solar radiation. The upper thermopile has a dome shaped window so that its field of view is 180 degrees, and that its angular characteristics fulfil the so-called cosine response as much as possible, in this field of view. It causes water droplets to run off more easily.

The field of view of the lower pyrgeometer is 150 degrees. It is limited due to the use of a flat window. This does not produce a large error because the missing part of the field of view does not contribute significantly to the total, and is compensated for during calibration.

There is no international standard that classifies pyrgeometers. Pyrgeometers have two specific properties that deserve special attention. The first is the so-called window-heating offset; the second is the influence of water deposition on the window.

#### 2.3.1 Window heating offset

The window heating offset is a measurement error that is introduced by the heating of the pyrgeometer window by the sun. It only occurs during the day. During a sunny day, the upper pyrgeometer will suffer from this. This error can be reduced by shading or ventilating. On a sunny windless day with a solar irradiance of 1000W/m<sup>2</sup>, an error of 6 Watts per square meter can be expected. The window will absorb part of the solar radiation and will heat up. As a result of this heating, heat will irradiate towards the thermopile. This results in an error source, in the Infrared range. This error is neglected, however, in the net radiation calculation this is justified because the solar radiation is always dominant when this error occurs. Due to its construction the window heating offset in the CNR 4 is extremely small compared with other instruments.

#### 2.3.2 Water deposition on the pyrgeometer window

The second specific error source of a pyrgeometer is the substantial measurement error introduced as the result of water deposition on the window. Water will completely obstruct the transmission of Far Infrared radiation. Water deposition will occur when it rains, snows, or when dew is deposited.

In the case of rain or snow, the resulting error is not very significant, mainly due to the fact that under these cloudy conditions, the pyrgeometer signal will be close to zero anyway. The cloud base temperature is generally close to ambient temperature. The conditions under which dew can form are much more likely to produce significant errors. A typical situation occurs at night, with a cloudless sky, low wind speeds, and high humidity (so-called clear, windless nights). Under these conditions, the upward-facing pyrgeometer signal is large, typically -100 Watts per square metre. When dew occurs, this reading can drop to zero, resulting in a 100 Watts per metre square error. Generally speaking this kind of error is too large, and if possible it should be avoided. Ventilation and heating can prevent dew deposition with the CNR 4's optional CNF 4. Heating will keep the instrument window above the dew point and ventilation will keep the domes clean from rain and snow.

#### 2.3.3 Specifications of the Pyrgeometer

The output of the pyrgeometer is a small voltage, in the mV range. It is proportional to the temperature difference between the pyrgeometer and the object that it faces. This implies that for calculation of the absolute quantity of Far Infrared radiation, that is emitted by the sky or the ground you also need to take the pyrgeometer temperature into account. This temperature is measured by a Pt-100 that is incorporated in the body of CNR 4. The calculation of the Far Infrared irradiance is described in chapter 1.

Pyrgeometer Specification	Unit	Value
Spectral range	µm	4.5 to 42 (50% points)

Definition		Instrument sensitivity within a specific spectral range
Sensitivity	$\mu\text{V}/\text{W}/\text{m}^2$	5 to 15
Definition		Calibration factor
Impedance	$\Omega$	20 to 200, typically 50
Definition		<i>Typical resistance measured at the output</i>
Response time	s	< 18 (95% response)
Definition		<i>Sensor response time</i>
Non-linearity	%	< 1 (from -250 to +250 $\text{W}/\text{m}^2$ irradiance)
Definition		<i>Maximum deviation from the responsivity at -100 <math>\text{W}/\text{m}^2</math> due to any change of irradiance within the indicated range.</i>
Temperature dependence of sensitivity	%	N/S (-40 °C to -10 °C) < 4 (-10 °C to +40 °C) N/S (+40 °C to +80 °C)
Definition		<i>Maximum error due to any change of ambient temperature with the indicated interval.</i>
Tilt error	%	< 1 deviation when tilted at any angle off horizontal.
Definition		<i>Maximum deviation from the responsivity at angular tilt with 1000 <math>\text{W}/\text{m}^2</math> beam.</i>
Window heating offset	$\text{W}/\text{m}^2$	< 6 (0 to 1000 $\text{W}/\text{m}^2$ / solar irradiance)
Definition		<i>Caused by heating of the dome due to solar radiation</i>
Field of view: Upper detector Lower detector		180° 150°
Definition		<i>Sensor opening angle</i>
Net irradiance range:	$\text{W}/\text{m}^2$	-250 to +250
Definition		<i>Measurement range</i>
Non-stability	%	< 1
Definition		<i>Maximum change per year, percentage of full scale</i>
Spectral selectivity	%	< 5 (8 – 14 $\mu\text{m}$ spectral range)
Definition		<i>Deviation of the product of spectral absorption and spectral transmittance from the corresponding mean within the indicated spectral range</i>
Environmental		humidity 0 - 100% RH
Definition		<i>Intended for continuous outdoor use</i>
Uncertainty in daily total	%	< 10 (95 % confidence level) Indoor calibration
Definition		<i>Achievable uncertainty</i>
Temperature sensor		Thermistor and Pt-100
<b>International standards</b>		
WMO ISO		Standards are not available
Instrument calibration		Indoors, side by side against reference CG(R) 3 pyrgeometer On request outdoors, side by side against reference CG(R) 4 pyrgeometer



### 2.3.4 Spectral properties of the pyrgeometer

The spectral properties of the pyrgeometer are mainly determined by the properties of the absorber paint and the silicon window. The silicon window is coated on the inside with an interference filter, which blocks the solar radiation. The spectral characteristics of the pyrgeometer are depicted in figure 2.5

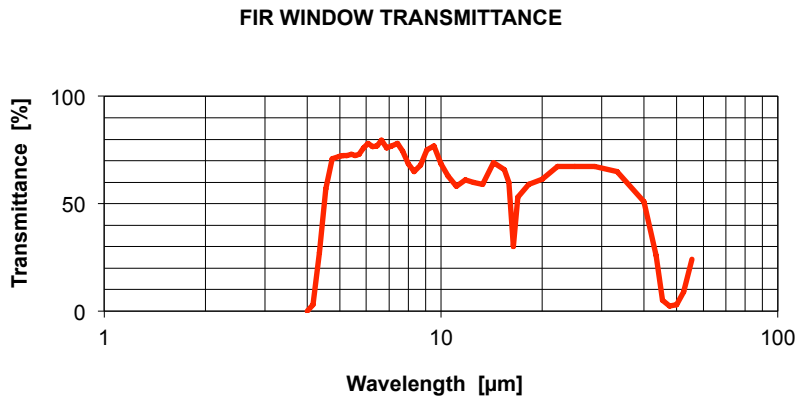


Figure 2.5 The spectral sensitivity of the pyrgeometer window: Theoretically it equals the spectral selectivity of the total instrument.

### 2.3.5 Directional / Cosine response of the pyrgeometer

The measurement of the Far Infrared radiation falling on a surface (also called irradiance or radiative flux) requires that the sensor has to comply with the cosine response.

A perfect cosine response will show a maximum sensitivity of (1) at an angle of incidence of 0° (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90° (radiation passing over the sensor surface). Between 90 and 0 degrees, the sensitivity should be proportional to the cosine of the angle of incidence.

## 2.4 Properties of the CNF 4 (optional) ventilation unit

The ventilator and heaters purpose is to prevent dew deposition on the pyrgeometer and pyrgeometer window, and thus increase measurement accuracy and reliability. Using the ventilator and heater will have negligible effect on the pyranometer reading.

Generally these errors are small relative to the errors that would have been caused by water deposition. More information for the pyrgeometer on this can be found in chapter 2.3.2

### 2.4.1 CNF 4 specifications

CNF 4 specifications	Unit	Value
Ventilation	W	5 W @ 12 VDC
Voltage	V	8 ... 13.5 VDC
Heater	W	10 W @ 12 VDC (15 Ohm)
Weight	kg	0.5 kg (CNR 4 + CNF 4 = 1.35 kg) <i>without cables</i>
Operating temperature:	°C	-40 to +80

There is one major reason for heating and ventilation: avoiding water deposition on the pyrgeometer window and on the pyranometer dome. In case of dew deposition on the pyrgeometer window, the dew will ultimately obstruct the Far Infrared radiation completely, causing a signal close to zero. In the case of rain, this will probably not lead to significant errors, because with an overcast sky the signal is close to zero anyway. The case of dew deposition is far more significant. Dew deposition will probably take place under conditions with large Far Infrared irradiation from the pyrgeometer detector to the clear sky, typically minus (-) 100 Watts per metre square. Under conditions where clouds or wind are present, dew is less likely to occur. A situation where dew depositing on the window of the pyrgeometer, causing a signal of -100 Watts per square metre to drop to zero, is certainly significant. If ventilation and heating can avoid this, it certainly should be done because all errors that are described above are much smaller than the gain in accuracy of 100 Watts per metre square.

For decisions about heating you can make the following diagram:

12 VDC, 6 VA available?	not available	Do not heat
	available	consider options below
Clock and relay available?	not available	heat all day, all night
	available	heat from 1 hour before sunset until one hour after sunrise.

The nominal power for the heater is 10 VA. In case of snow or frost you might also consider heating at a higher level than the usual. Heating at 20 VA will melt snow in most cases. 20 VA can be reached at 24 Volt. If lower voltage is available, you might consider heating at a lower power. The 10 VA is designed for extreme conditions. 5 VA (at 6V) is sufficient for moderate conditions.

Time needed for reaching a stable instrument temperature when heating is about 60 minutes.

## 2.5 Properties of the Pt-100 and thermistor

The Pt-100 is a common temperature sensor. Essentially it is a resistor that is temperature dependent. The Pt-100 complies with the specifications of DIN, class A. A table stating the resistance values can be found in chapter 1.1.6.3

Alternatively the thermistor, (nominal value is 10k Ohms at 25 degrees Celsius) can be used. A table stating the resistance values can be found in table 1.1 The thermistor has a much larger resistance value than the Pt-100, also the change in resistance with respect to temperature, in absolute terms, is greater. Therefore the cable resistance can be neglected, and only a 2-wire connection is used for the thermistor measurement, contrary to the 4-wire connection of the Pt-100.

The accuracy of both temperature sensors is equal and the selection to use one or the other mainly depends on the possibilities of the connected data logger or data acquisition system.

### **3 CALIBRATION**

#### **3.1 Calibration of the pyranometers**

The primary standard for pyranometers is the World Radiometric Reference. Reference pyranometers that are used at Kipp & Zonen are calibrated using the primary standard.

The Kipp & Zonen pyranometer calibration is traceable to the World Radiometric Reference.

Further reference conditions are as follows: temperature 20 degrees Celsius, irradiance 500 Watts per metre square, in the horizontal position. Each pyranometer has an individual calibration factor.

These factors can be found on the calibration certificate, included with the instrument and on the label applied on the instrument itself.

#### **3.2 Calibration of the pyrgeometers**

There is no primary standard for pyrgeometer measurements.

The pyrgeometers in the CNR 4 are calibrated relative to the reference that is present at Kipp & Zonen.

In turn this reference has been calibrated against the World Reference at WMO in Davos

#### **3.3 Recalibration of pyranometers and pyrgeometers**

We suggest recalibration for all sensors, pyranometers, and pyrgeometers to be performed every two years by an authorised Kipp & Zonen calibration facility, 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, you should use a clear day. For comparison of pyrgeometers, you should compare night time results.

#### **3.4 Checking the Pt-100 and Thermistor**

Please check the reliability of the Pt-100 / Thermistor measurement by doing a parallel measurement with the other temperature sensor. If this is not possible it can be done by temporarily attaching a stick-on type thermocouple to the CNR 4's body, and then subsequently comparing the readout of the thermocouple with the readout of the Pt-100 / Thermistor. The discrepancy, assuming that the thermocouple has a +/- 0.2 degrees accuracy, should be within +/- 0.7 degrees. If it is greater, the deviating temperature sensor should be replaced.

## 4 INSTALLATION AND MAINTENANCE

For measurement of the Net Radiation, it is most important that the instrument is located in a place that is representative of the entire region that you wish to study.

When installed permanently, the net radiometer should be attached to its mounting platform with the rod that is attached to its body.

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.

It is suggested that the CNR 4 is mounted at a height of at least 1.5 metres above the surface, to avoid shading effects of the instruments on the soil and to promote spatial averaging of the measurement. If the instrument is H metres 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 Net Radiometer should be installed horizontally, using the level on the body of the CNR 4.

For installation in buildings or in solar energy applications, you will often have to mount the CNR 4 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 in chapter 2.2.1 and 2.3.3 you can see that the tilt effect (this is change in sensitivity) remains within 1 %.

### 4.1 Replacing the drying cartridge

The Net Radiometer is an all-weather instrument.

Once installed it needs little maintenance. It is suggested that you clean the windows and domes as part of a regular routine, using water or alcohol. The drying cartridge needs to be replaced every 2 years. The 3 screws for the plastic cover and the 6 screws for the base plate need to be removed using a screwdriver with a Philips tip size PH1. Under the base plate the drying cartridge is located. The (black) rubber ring as indicated in the picture below must be in place to keep the compartment sealed.

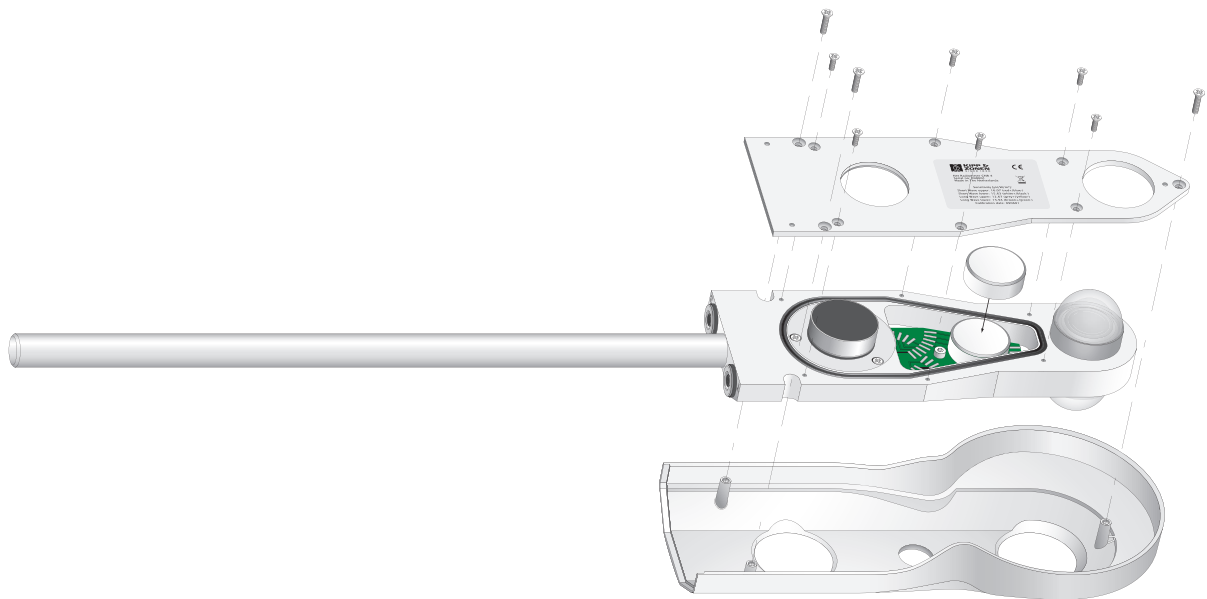


Figure 4.1 Replacing the drying cartridge

#### 4.2 Replacing the Ventilator Filter

The CNF 4 ventilation unit has a filter that can be checked and if required cleaned or replaced. The cover of the ventilator cover (black part in picture below) can be removed by just pulling it down from the CNR 4. The filter needs to be checked for dust and particles every 6 - 12 months. It can be cleaned by simply washing it in clean water or it can be replaced by a new one. To remount the cover and filter just click it back on the ventilator.

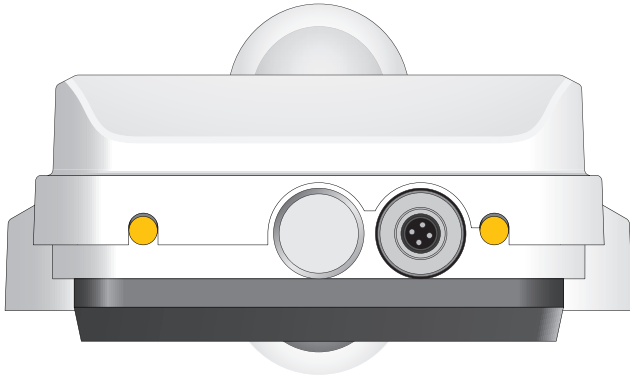


Fig 4.2 Back of CNF 4 with filter cover

## 5 TROUBLE SHOOTING

This chapter describes what to do if there appears to be a problem. The following chapters give individual information for checking the pyranometer, pyrgeometer, the temperature sensors and the ventilation unit with heater.

All connections to the CNR 4 are made with connectors and cables that can be separated from the main instrument. Check at all times that these connectors are properly attached and screwed to the body of the CNR 4.

If there is no clue as to what may be the problem, start performing the following "upside-down test", which is a rough test for a first diagnosis. It can be performed both outdoors and indoors. Indoors, a lamp can be used as a source for both Solar and Far Infrared radiation. Outdoors you should preferably work with a solar elevation of more than 45 degrees (45 degrees above horizon) and of course under stable conditions (no large changes in solar irradiance, preferably cloudless) :

1. Measure the output in the normal position. Record the measured values when the signals have stabilised, i.e. after about 3 minutes.
2. Rotate the instrument 180 degrees, so that the upper and the lower sensors are now in the reverse orientation as to the previous position.
3. Measure the output once more. Record the measured values when the radiometers have stabilised.
4. The calculated radiation for the sensors in the rotated position should be equal in magnitude, only differing in sign. In a rough test like this, deviations of +/- 10 % should be tolerated. If deviations greater than this are encountered, the following tests might help.

### 5.1 Testing the pyranometer

As a first test we recommend that you check the sensor impedance. It should have a nominal value between 20 and 200 Ohm. Zero, or infinite resistance indicates a failure in hardware connection.

Before starting the second test measurement, let the pyranometer rest for at least five minutes to let it regain its thermal equilibrium. For testing, set a voltmeter to its most sensitive range setting. Darken the sensor. The signal should read zero. Bear in mind that the response takes about one minute. Small deviations from zero are possible; this is caused by thermal effects like touching the pyranometer with your hand. The latter effect can be demonstrated by deliberately heating the pyranometer with your hand. Another cause might be the zero offset of the data logger. When this is the case, the same offset will also be present when the data logger is short-circuited with a 200 Ohm resistor. This is an amplifier error from the data logger. This amplifier error should not be larger than 5 Watts per square meter. If the amplifier error is within specifications, proceed with the third test.

In the third test the sensor should be exposed to light. The signal should be a positive reading. Set the voltmeter range in such a way that the expected full-scale output of the pyranometer is within the full-scale input range of the voltmeter. The range can be estimated on theoretical considerations. (When the maximum expected radiation is 1500 Watts per square metre, which is roughly equal to normal outdoor daylight conditions, and the sensitivity of the pyranometer is 15  $\mu\text{V}$  per Watt per square metre, the expected output range of the pyranometer is 1500 times 15 which is equal to 22500  $\mu\text{V}$ , or 0.0225 Volts). You can calculate the radiation intensity by dividing the pyranometer output (0.0225 volts) by the calibration factor (0.000015 volt per watt per square metre). Still no faults found? Your pyranometer is probably doing fine.

### 5.2 Testing of the pyrgeometer

It is assumed that the data logger (amplifier) circuit is the same as the one used for pyranometer, and that its zero offset is no more than a few watts per square metre, let us say 5 Watts per square metre just as an example, (see test in 5.1).

The CNR 4 body and ambient air should be at the same temperature as much as possible. Let the pyrgeometer rest for at least five minutes to regain its thermal equilibrium. Set the voltmeter to its most sensitive range. To test if the pyrgeometer is working properly, we suggest putting your hand in front of the pyrgeometer. The thermal radiation will cause pyrgeometer to generate a positive voltage when the hand's surface temperature is higher than the pyrgeometer temperature. The pyrgeometer will generate a negative voltage if the hand is colder. The signal is proportional to the temperature difference (see the rule of thumb of 1.1.6.5). The radiation that is emitted by the hand can be calculated by dividing the pyrgeometer output by the calibration factor, and subsequently correcting for the temperature, according to equation 1.2. Still no faults found? Your pyrgeometer is probably doing fine.

### **5.3 Testing the Pt-100**

Using a meter, which measures resistance, you can check the operation of the Pt-100. If connected properly, the resistance of two opposite wires of the Pt-100 should be measured. The value can be read in the table 1.1 and should be above 100 Ohms (cable resistance should measure about 0.1 ohms per metre cable). When in doubt the thermistor resistance (temperature) can be checked as well for reference

### **5.4 Testing the thermistor**

Using a meter, which measures resistance, you can check the operation of the thermistor. If connected properly, the resistance of two wires of the thermistor should be measured. The value can be read in the table 1.2 and should be around 10.000 Ohms for 25 °C. (cable resistance should measure about 0.1 ohms per metre cable). When in doubt the Pt-100 resistance (temperature) can be checked as well for reference

### **5.5 Testing the Heater**

The optional CNF 4 consists of a heater and ventilator. Using a meter, which measures resistance you can check the operation of the heating resistor. The value should be around 15 Ohm. (Cable resistance should measure about 0.1 ohms per metre cable).

Using a meter, which measures resistance, you can check the operation of the heater. If connected properly, the resistance of two opposite wires of the heater should measure about 8 ohms (this includes the cable resistance for the standard 10-meter cable). The cable resistance should measure about 0.1 ohms per metre cable. An infinite resistance reading indicates the likelihood of a broken wire, or cable.

### **5.6 Testing the Ventilator**

The impedance of the ventilator motor can be checked to tested for reference The value should be around 30 Ohms (cable resistance should measure about 0.1 ohms per metre cable). In this case a correct value is measured this does not guarantee proper operation. It is possible the ventilator is stalled by an object blocking the fan. This can be checked by removing the cover and filter and inspecting the rotation of the fan by hand.



## 6 CMB 1 OPTIONAL MOUNTING BRACKET

The CMB 1 mounting bracket is ideal for mounting the CNR 4 to a pole or wall. The stainless steel construction ensures a durable fixation to almost any object. The top U bolts allow rotation of the CNR 4 rod, while the extra screw under the front U bolt allows the rod to tilt. All mounting material for fixation to a horizontal or vertical pole is included. The 2 different sized pairs of U bolts allow for pole sizes between 22 mm and 60 mm. Wall mounting bolts and or plugs are not included.

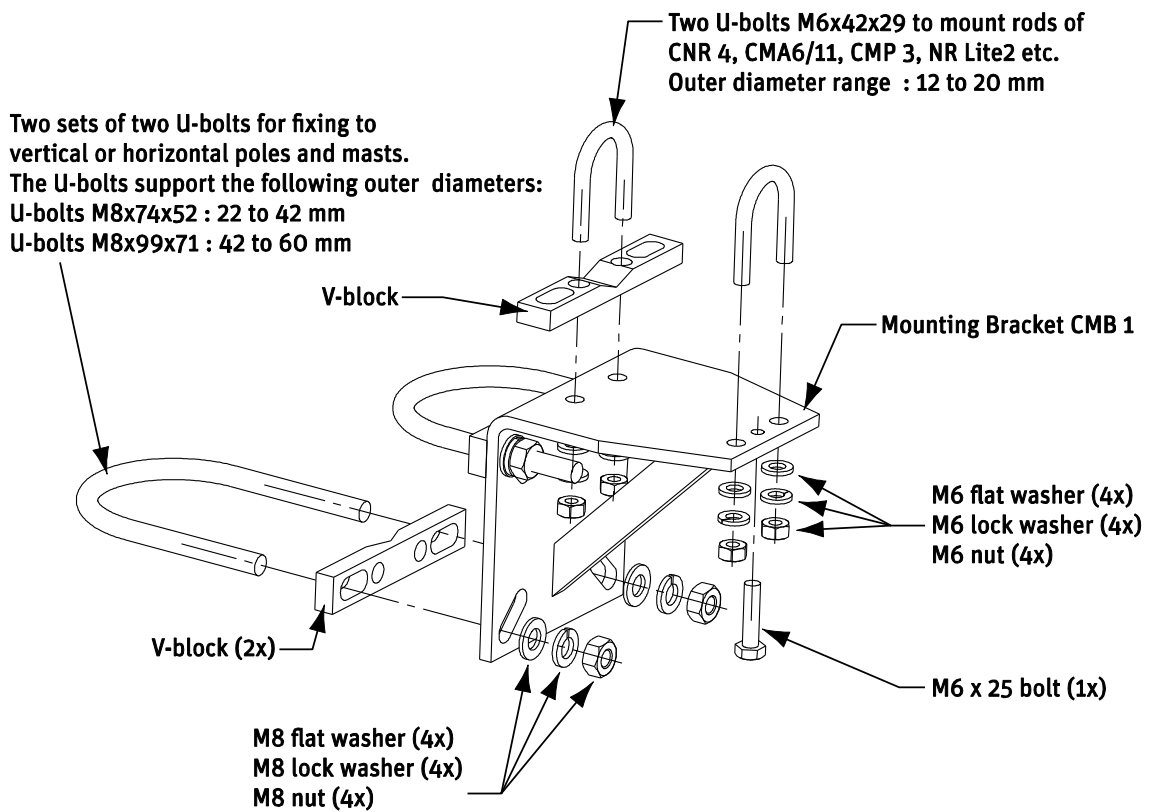


Fig 7.1 CMB 1 mounting bracket with mounting material

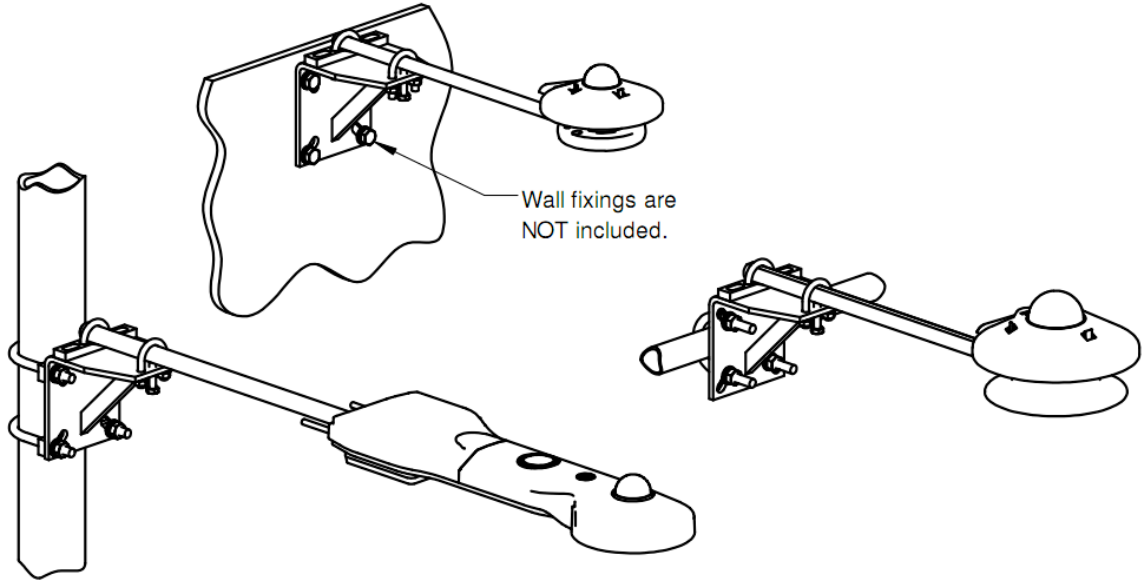


Fig 7.2 CMB 1 mounting examples with CNR 4, albedometer and pyranometer

## 7 DELIVERY

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport. If there is damage, a claim should be filed with the carrier immediately. In this case, or if the contents are not complete, your dealer should be notified in order to facilitate the repair or replacement of the instrument.

The CNR 4 Net-Radiometer delivery will include the following items:

A delivery includes:	One CNR 4 One mounting rod Two cables Two drying cartridges Four calibration values on 2 calibration sheets (long and short wave) One CD with instruction manual
Optional CNF 4	One CNF 4 mounted to the CNR 4 One (4 wire) cable

### Unpacking

Keep the original packaging for later shipments (e.g. recalibration)!

Although all sensors are weatherproof and suitable for harsh ambient conditions, they do partially consist of delicate mechanical parts. It is recommended to use the original shipment packaging to safely transport the equipment to the measurement site.

## 8 RECALIBRATION SERVICE

### **Pyranometers, UV-meters, pyrgeometers, Net radiometers & Sunshine duration meters**

Kipp & Zonen solar radiation measurement instruments comply with the most demanding international standards. In order to maintain the specified performance of these instruments, Kipp & Zonen recommends calibration of their instruments at least every two years.

This can be done at the Kipp & Zonen factory. Here, recalibration to the highest standards can be performed at low cost. Recalibration can usually be performed within four weeks. If required, urgent recalibration can be accomplished in three weeks or less (subject to scheduling restrictions). Kipp & Zonen will confirm the duration of recalibration at all times. Please note that special quantity recalibration discounts are available.

Please contact us at:

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The Netherlands

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