Test and Installation of an Automatic Weather Station to Provide Ground-Based FTIR Measurements for TCCON

Fachhochschule Jena
University of Applied Sciences Jena

Max-Planck-Institut
für Biogeochemie

Diploma Thesis

by
Hendrik Zöphel
Mat.Nr.: 488470
born 18. October 1979

Supervised by
Dr. Dietrich Feist
Prof. Dr. Andreas Schleicher

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University of Applied Science Jena, Germany

Affidavit

I hereby declare on oath that this thesis is my own work and that it contains no material previously published, or substantially overlapping with material submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

Ich versichere hiermit an Eides statt, dass ich diese Arbeit selbst verfasst habe und das diese kein bereits veröffentlichtes, sowie Material aus anderen Diplomarbeiten zur Erlangung eines akademischen Grades enthält, ausgenommen der im Text auf Literatur verwiesenen Stellen.

Jena, 26. November 2008 ....

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In particular, I thank my friends Stephan Baum, Sebastian Klein, Carolin König and Roberto Kretschmer - most of all - my family and Kristin Pohl for their neverending support, without which I would not have been able to complete this work.

Extra appreciation goes to all authors of the papers and manuals which I used within my thesis.

Abstract

Measurements with the MPI-BGC FTIR system are only possible when the sun is visible. However, the solar tracker which guides the sunlight into the instrument has to be protected from precipitation and other adverse environmental conditions. Therefore the FTIR system needs a weather station to determine if the local weather conditions are favourable for measurements or if the solar tracker should be protected.

Figure 1: The BGC-FTIR Weather Station

The main parameters which will be determined are temperature, humidity, solar radiation, wind speed and precipitation. To increase the reliability of the system, all of the crucial parameters are measured redundantly with duplicate sensors or sensors of different principle. The redundant sensor principle is also useful to correct long-term drift of the sensors.

The temperature and the humidity are measured with two compact meteorological sensors. The wind speed is provided by two cup anemometers with high reliability. The precipitation is detected by a light barrier and a contact conclusion system. A pyranometer provides measurements of the global solar radiation. The high precision pressure measurement is implemented with a digital sensor which provides maximum accuracy as well as long-term stability. A thermistor and a digital temperature/humidity sensor are used for monitoring the conditions inside container.

The sensor signals are collected by the Datalogger CR1000 at several analog and digital inputs. The CR1000 and the sensors form a completely autonomous system which works close together with the other systems installed in the Container. Thus, this automated measurement system is possible. Communication with the master PC is accomplished over an ethernet connection with the Ethernet/Compact Flash Module NL115. Furthermore it makes it possible to be flexible in programming via FTP, for example to adjust calibration factors, to balance the offset or to upload a new program. The data are finally stored in tables on the CPU as well as on the CF-Card.
The common handling of the automatic weather station was documnented in the form of a comprehensive instruction manual which will be added to the documentation of the BGC-FTIR-Container.

The weather station was built as an efficient autonomous and easy to use system. This system operates close together with the other systems in the container to provide the required data for an fully automatic measurement system - the BGC FTIR-Container

Contents

Chapter 1

Scope

The Earth's climate has changed throughout the history. From glacial periods or "ice ages" where ice covered significant portions of the Earth to interglacial periods where ice retreated to the poles or melted entirely - the climate has continuously changed.

Figure 1.1: Greenhouse Gas Cycle
[http://oco.jpl.nasa.gov/images/greenhouse-sm1.gif, 12.09.08]

There are a lot of factors effecting the climatic behaviour of the Earth. CO_2 is a critical component of the Earth's atmosphere. Since the beginning of the industrial age, there has been a concentration increase of CO_2 of about 25%, from about 280 parts per million to over 370 parts per million. Scientific studies indicate that CO_2 is one of several gases that trap heat near the surface of the Earth. These gases are known as greenhouse gases [1]. Figure 1.1 shows the global greenhouse gas cycle.

Many scientists have concluded that substantial increases in the abundance of CO_2 will generate an increase in the Earth's surface temperature. Historical records provide evidence of this trend, which is often called global warming. Current research indicates that continuing increases in atmospheric CO_2 may modify the environment in a variety of ways. These changes may impact ocean currents, the jet stream and rain patterns. Some parts of the Earth might actually cool while the average temperature increases. Thus, a more correct term for this phenomenon is climate change. CO_2 can enter the atmosphere from a variety of sources. Some sources are natural, such as rotting plants, forest fires and ordinary breathing. Human activities augment the emission of CO_2 into the atmosphere. Automobiles, factories and home heating units burn fossil fuels such as oil, coal and natural gas. Burning these fossil fuels releases CO_2 into the atmosphere. Other natural processes remove CO_2 from the atmosphere. Plants use sunlight to photosynthesize CO_2 and water into sugar and other carbohydrates. The oceans also absorb atmospheric CO_2. Sea creatures incorporate the CO_2 dissolved in sea water into their shells. After the death of these creatures, their shells fall to the bottom of the ocean. Over time, these sediments form carbonate rocks. Processes that absorb CO_2 from the atmosphere are often referred to as sinks. The complete process of CO_2 exchange is known as the carbon cycle [1].

In order to improve the understanding of the carbon cycle, the Carbon Dioxide Information Analysis Center of the U. S. Department of Energy tracks and monitors CO_2 emissions from a global network of ground-based sites. This network provides a tremendous amount of insight into the global abundance of CO_2 and its variability of changes in seasons [1].

Unfortunately, the global network does not include enough stations to resolve the spatial distribution of CO_2 sources and sinks at the scale of continents or ocean basins. Thus, even with these extensive measurements, the processes that regulate the exchange of CO_2 between the atmosphere, the oceans, and the biosphere are not completely understood. One of the ground-based measurement projects that collaborates with the Carbon Dioxide Information Analysis Center of the U. S. Department of Energy is the Total Carbon Column Observing Network (TCCON). Figure 1.2 will give you an overview of the operational and the future site of ground-based measurement stations from TCCON. Austria, the US, Japan, Spain, New Zealand and Germany are involved so far and more will come along.

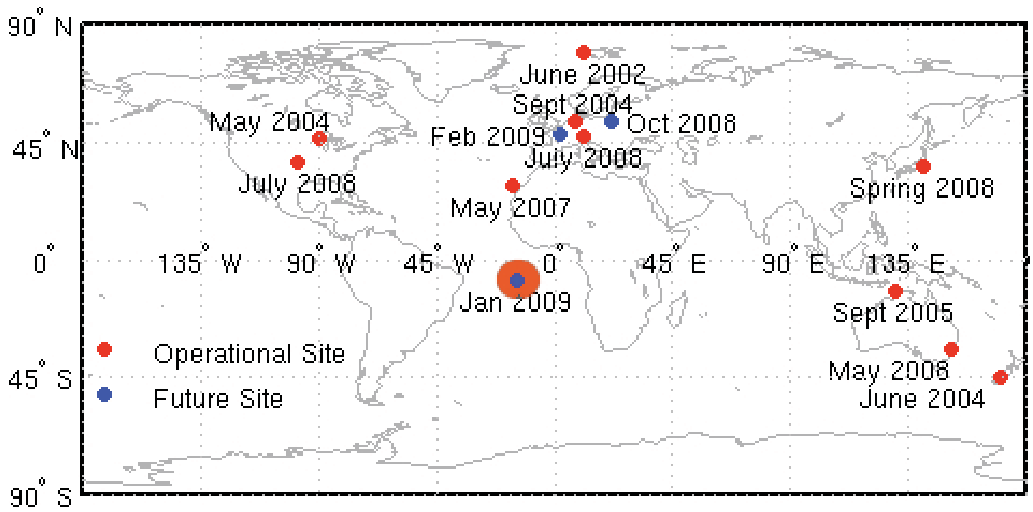


Figure 1.2: Operation and Future Site of ground-based Measurement Stations [http://www.tccon.caltech.edu/images/tccon_080723.png, 12.09.09]

Thus, TCCON is a global network of ground-based fourier transformation spectrometers recording direct solar spectra in the near infrared spectral region from 4000 to 14000 cm^{-}1. From these spectra, accurate and precise column-averaged abundance of CO_2, CH_4, N_2O, HF, CO, H_2O and HDO can be retrieved [2].

The column observation, in combination with the existing and growing surface measurements, will improve estimates of surface flux of greenhouse gases, allowing improved predictions of their future concentrations, and ultimately climate. In addition to their direct use for carbon flux studies, TCCON measurements will be used to validate satellite column measurements for the Orbitting Carbon Observatory (OCO), Scimatchy and the Global Greenhouse Observation by Satelite (GOSAT).

Several of the TCCON sites have been either fully or partly funded for validation of the NASA OCO satellite. To provide useful constraints for the global carbon budget the measurements must achieve a precision approaching 0.1%.

Within my diploma thesis my work will account for ground-based FTIR measurements by making a contribution for building up a fully automatic measurement system - the BGC-FTIR-Container.

Figure 1.3: BGC-FTIR-Container

This container will likely takes up work on Ascension Island in the first quarter of 2009 for measuring CO_2 and CH_4 by means of the solar spectrum for carrying these data forward into TCCON's database. The ireland with its capital Georgetown is situated in the south atlantic ocean, shown in Fig. 1.2, 7 °56' 38" South and 14 °21' 51" West. It has tropical climate and a population of 1100 people inhabiting an area of 91 km^2.

Chapter 2

The Sensors

2.1 Weather Station - Instrumentation

The intended goal of the use of the weather station is to provide all the meteorological data which are required for measuring a solar spectrum by means of the BGC-FTIR-System as well as to make this system completely automatic. Figure 2.1 shows the weather station.

Figure 2.1: The BGC-FTIR Weather Station

To increase the reliability of the system, all crucial parameters are measured redundantly with duplicate sensors or sensors of different principle. The redundant sensor principle is also useful to correct long-term drift of the sensors. The following notes will give an overview of the used sensors, their function in the BGC-FTIR-System and their measuring principle.

2.1.1 Temperature/Humidity - Galltec/Mela KPC 1/6-ME

Function

Temperature and humidity are not only fundamental, but also crucial parameters, within the measuring process of the BGC-FTIR-Container. So longterm recordings outside the BGC-FTIR-Container are done to find out possible discrepancies in solar spectra. Furthermore, these measurements contribute to avoid condensation on the mirror‘s surface of the solar tracker in case of humidity levels at high ranges.

Figure 2.2: KPC 1/6-ME and Weather Guard
[Manual - Product Info Sheet No. C 2.4, 3/04]

Figure 2.2 shows the Galltec/Mela KPC 1/6-ME. This compact sensor has a rod-type design with a high degree of accuracy. It has been especially developed for meteorological applications and provides with its redundant use maximum reliability for the system.
The sensor can be exposed to salt mist because of its location close to the sea. Thus, it is used the version with the ZE21-type sintered high-grade steel filter in order to protect the sensing element and to reduce maintenance. Therefore the dynamic behavior changes as one can see in section 5.1.1 on page 52.

Measuring Principle

To measure temperature, the sensor uses a platin PT100 temperature probe whose basis is a resistance varying according to its temperature.

This sensor element is distinguished through its nominal resistance R_0 of 100 ohm. Humidity is measured by use of a capacitive sensor element. Thus, the humidity sensor forms a capacitor with its environment. If there are any changes in humidity, there are also changes in capacitance of the capacitor because of the difference in permittivity. Figure 2.3 shows the capacitive sensor principle. The capacity is calculated with equation 2.1.

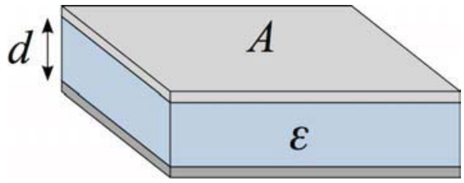


Figure 2.3: Capacitive Sensor Principle [http://upload.wikimedia.org/wikipedia/commons/2/20/PlateCapacitorII.svg, 10.10.08]

$$C_0 = \epsilon_0 \epsilon_r \frac{A}{d} \tag{2.1}$$

- C_0 = Capacity [F]
- ϵ_0 = Permittivity Constant [Fm^{-1}]
- ϵ_r = Permittivity [Fm^{-1}]
- A = Area [mm^2]
- D = Distance [mm^2]

The higher the rate of water, the higher the permittivity and therefore the higher the capacitance. This change is detected by the connected electronics of the sensor and allocated as an electrical output signal. The output signal is proportianal to the changes in capacitance.

The structure of the sensing element is demontrated in Fig. 2.4.
There is a thin gold layer, a hygroscopic polymer layer, a electrode system and a ceramic substrate.

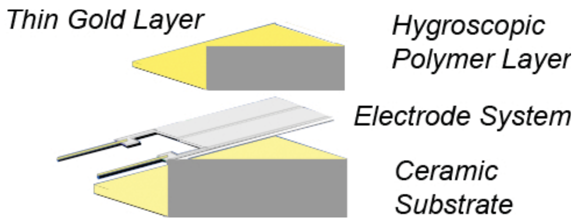


Figure 2.4: Sensing Element
[Physics of the Humidity Technology,
R. Freitag, PowerPoint Presentation, 4/07]

The Polymer is to be poised with the environment and store water, where the thin goldlayer is water vapour permeable. By this means a storage of the H_2O-dipol causes a change of the dielectric within the capacitor which depends on frequency. So capacity increases by availability of charge carriers which is detected within the connected electronics for further converting processes.

2.1.2 Wind Speed - Lambrecht 14577

Function

When weather condition are characterized by high wind speeds, the dome of the solar tracker should close for protecting the sensitive instrument. Thus, wind speed is one of the parameters which is determined for protecting the solar tracker. If high wind speeds do occure at a high level a signal is send to the control system of the BGC-FTIR-Container, the SPS, to close the dome of the solar tracker. To increase the reliability of the system, the wind speed is provided by two cup anemometers.

Figure 2.5: Lambrecht Wind Speed 14577
[Manual - Wind-Sensors INDUSTRY 145x7, 10/06]

The sensor is shown in Fig. 2.5. Its main advantages are the electromagnetic, non-impact measuring principle for precise data acquisition with high resolution and the double supported ball bearing of the rotation axis. These characteristics assure high reliability, longevity, lower friction as well as lower abrasion and high accuracy. Furthermore, there is an automatic heating element to avoid freezing of the ball bearing.

Measuring Principle

Measuring wind speed is implemented with an integrated circuit (IC) including a hall-sensor-array. The IC is measuring the change in alignment of the magnetic field by means of a rotating magnet which is mounted at the cup module of the anemometer. This information of changing by time is going to be processed in the connected microcontroller in order to have an analog output for wind speed. Unfortunately, there are no further detailed information about the measuring principle from the manufacturer.

2.1.3 Precipitation - Lambrecht 15153

Function

Figure 2.6 shows Lambrecht's precipitation detector. This sensor transmits signals to determine the beginning and the end of precipitation and the duration of the period of precipitation.

Figure 2.6: Lambrecht Precipitation Sensor 15153
[Manual - Electronic Precipitation Indicator 15153, 1/07]

In the BGC-FTIR-System this sensor is used to report status and to transmit a control signal to the SPS to protect the solar tracker by closing the dome in order to avoid wetting of the sensitive instrument. The sensor is equipped with a heating system for extreme weather conditions. This avoids ice and snow forming on the housing's surface and increases the reliability of the system.

Measuring Principle

Precipitation in the form of drizzle, rain, snow or hail is detected by means of an IR light barrier system as shown in Fig. 2.7.
Infrared radiation is send and received by a photo diode. If this event is cut through a signal is triggered within the connected electronics and reports precipitation.

The control system of the BGC-FTIR-Container processes this event for further steps concerning the protection of the solar tracker.

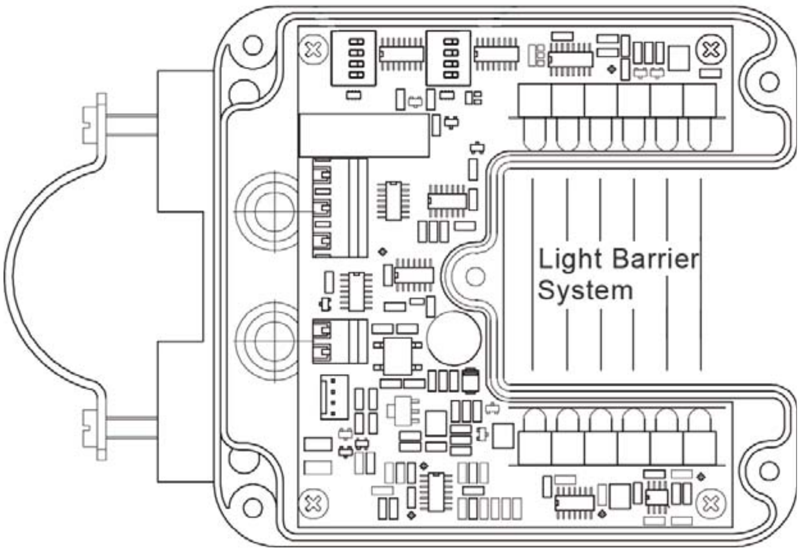


Figure 2.7: Sensors Light Barrier System
[Manual - Electronic Precipitation Indicator 15153, 1/07]

A built-in incidence-filter smoothes the triggering of swiching signals in case of individual incidences, as for example leafs, bird droppings, insects etc. For this, a certain number of at least "n" incidences should have occured within a time-frame of 50 seconds. The number of drop incidences (1...15) can be selected through the DIP switch on the circuit board. For details please see [16]. When precipitation ends, the switching signal is reset after a selectable switch-off delay.

2.1.4 Precipitation - Lambrecht 15152

Function

In order to provide a detection of all kinds of precipitation the precipitation instrumentation is enlarged by the Lambrecht 15152. It is a very simple but reliable sensor as shown in Fig. 2.8.

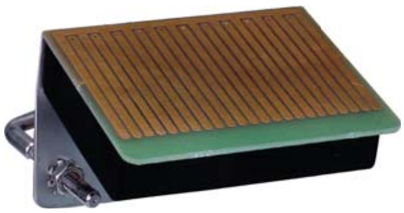


Figure 2.8: Lambrecht Rain Sensor 15152
[Manual - Electronic Rain Indicator 15152, 6/07]

The sensor‘s surface is heated in two levels. The first level is switched on constantly to prevent ice and dew formation. As soon as the sensing area is moistured, the second heating level is switched on to make sure that the surface drys up as soon as possible. After drying up the second level is switched off again. So a use at every weather condition is implemented.

Measuring Principle

At the beginning of a precipitation event rain drops will cause a conductive connection between the two sensing electrodes to trigger the relay contacts. By this means a relay is cut through and the controlling event is done. The SPS process this event for further protection steps.

2.1.5 Solar Radiation - Kipp & Zonen CMP3

Function

Measurements with the BGC-FTIR-System are only possible when the sun is visible. Therefore the Pyranometer CMP 3 comes into operation to determine if the local conditions are favourable for measuremnts or not. Figure 2.9 shows the instrument.

Figure 2.9: Kipp & Zonen CMP3
[http://www.campbellsci.com/images/cmp3.jpg, 02.09.08]

The use of the CMP 3 is intended for shortwave global solar radiation measurements (spectral range 310 to 2800 nm) and measures irradiance up to 2000 W/m^2 with a response time less than 18 seconds.

Measuring Principle

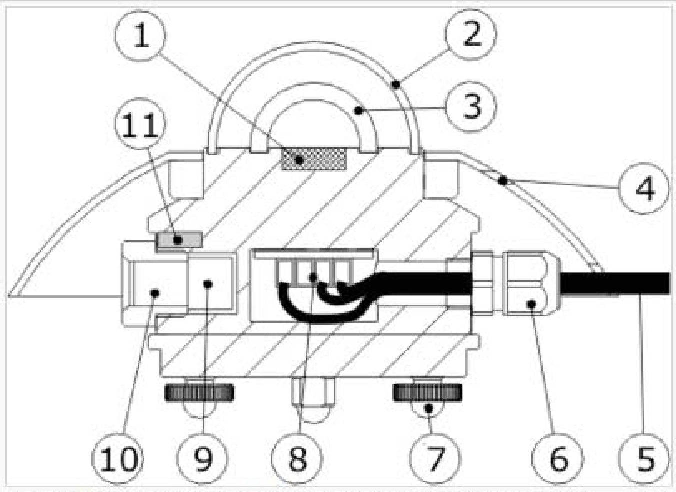
The thermopile sensor construction measures the solar energy that is received from the total solar spectrum and the hole hemisophere (180 degrees field of view). The output is expressed in W/m^2 according to equation (2.2).

$$E_{solar} = \frac{U_{emf}}{S} \tag{2.2}$$

- E_{solar} = Irradiance [W/m^2]
- U_{emf} = Output Voltage [V]
- S = Sensitivity [V/(W/m^2)]

In order to attain the proper directional and spectral characteristics, the pyranometer‘s main components are fundamental as shown in Fig. 2.10 according to [13].

The most important components are the thermopile sensor with a black coating, which absorbs all solar radiation, has a flat spectrum covering the 300 to 50000 nanometer range and has a near-perfect cosine response as well as the glass dome. This dome limits the spectral response from 310 to 2800 nanometers (cutting off the part above 2800 nm) while preserving the 180 degrees field of view. Another function of the dome is the shielding of the thermopile sensor from convection and other adverse environmental conditions.



thermopile sensor(1), domes (2), glass dome (2, 3), radiation screen (4), signal cable (5), gland(6), leveling feet (7), printed circuit board(8), desiccant (9), level (11).

Figure 2.10: Main Components
[http://en.wikipedia.org/wikiImage:
Pyranometer_sr11_hukseflux_crosssection.gif, 24.09.08]

The black coating on the thermopile sensor absorbs the solar radiation. This radiation is converted to heat. The heat flows through the sensor to the pyranometer housing. The thermopile sensor generates a voltage output signal that is proportional to the solar radiation.

2.1.6 Pressure - Vaisala PTB210

Function

The pressure measurement requires high accuracy and precision to calculate volume mixing ratio of the measured trace gases. These data are also measured to be archieved with the solar spectrum in the database of the TCCON network for further processing. Thus, the automatic weather station is equipped with two digital Vaisala PTB 210 which features digital output in an range of 500 to 1100 hPa. A third sensor of the same type is used for the leap-frog recalibration scheme. All of them are operating in a wide temperature range and the rugged corrosion-resistant housing provides an IP65 standardized protection against sprayed water.

Figure 2.11: Vaisala PTB 210
[Manual - PTB210 Digital Series with Serial Output, 12/05]

To maintain the reliability of the system the leap-frog recalibration scheme is carried out according to figure 2.12.

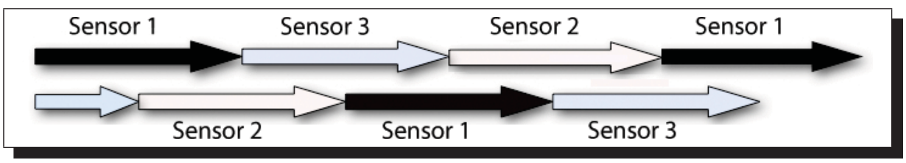


Figure 2.12: Leap-Frog Recalibration Scheme

The sensor is shown in Fig. 2.11. Two barometers are always used for operational measurements. Upon every maintenance visit, one of the barometers should be replaced with the recalibrated spare one. This way you can ensure that there is a maximum in accuracy and precission for further calculations.

Measuring Principle

The PTB210 barometers incorporate the BAROCAP silicon capacitive absolute pressure sensor developed by Vaisala [8] . The BAROCAP principle can be found in 2.13. The sensor features excellent hysteresis and repeatability characteristics and has an outstanding temperature and long-term stability.

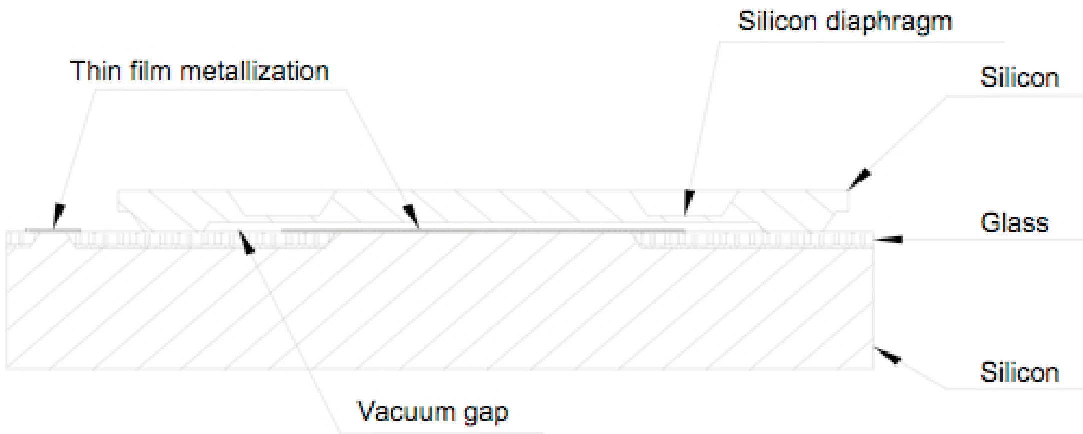


Figure 2.13: The BAROCAP Pressure Sensor
[Manuel - PTB210 Digital Series with Serial Output, 12/05]

The sensor consists of two layers of single crystal silicon having a layer of glass between them. The thinner silicon layer creates an integrated vacuum reference chamber and forms a pressure-sensitive silicon diaphragm. The thicker silicon layer is the rigid base plate of the sensor and is clad with a glass dielectric. Thin film metallization is deposited to form a capacitor electrode inside the vacuum reference chamber. The other electrode is the pressure-sensitive silicon diaphragm. When pressure changes, the silicon diaphram bends and changes the height of the vacuum gap in the sensor. This changes the capacitance of the sensor which is measured and converted into a pressure reading [18].

2.2 BGC-FTIR-Container - Monitoring

It is not only important to provide all the meteorological data, you also have to bear in mind the conditions inside the BGC-FTIR-Container. In oder to do this several sensors are mounted for monitoring the crucial parameters in case of a failure in air conditioning or simply to control temperature inside the FTIR instrument.

2.2.1 Temperature Probe - Campbell Scientific T107

Function

A low pressure gas cell filled with HCL is used to provide narrow absorption lines at a number of different frequencies across the bandwidth of the FTIR instrument. The gas cell acts as an internal calibration reference and is placed directly into the solar beam. Campbell Scientific‘s Temperature Probe T107 is shown in Fig. 2.14. It is used for monitoring the temperature inside the FTIR spectrometer next to the gas cell because absorption lines depend on temperature. Two redundant sensors are used for monitor the temperature of the gas cell.

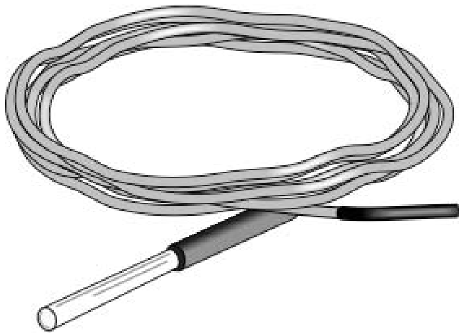


Figure 2.14: Temperature Probe T107
[Manual - Model 107 Temperature Probe, 4/07]

Measuring Principle

The Temperature Probe T107 uses a thermistor to measure temperature. This thermistor is a kind of resistor with resistance varying according to its temperature. The sensor measures the voltage drop across the 1K ohm resistor according to Fig. 2.15.

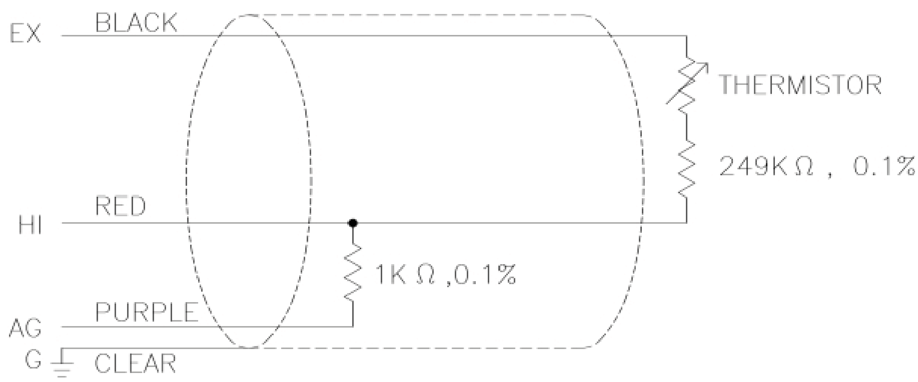


Figure 2.15: Thermistor Probe Schematic
[Manual - Model 107 Temperature Probe, 4/07]

The ration of measured voltage (Vs) to the excitation voltage (Vx) is related to the thermistor resistance (Rs), and the 1000 and 249K ohm fixed resistor shown in equation 2.3 below.

$$Vs/Vx = \frac{1000}{Rs + 249000 + 1000} \tag{2.3}$$

The sensor calculates Rs from the voltage ration, and converts Rs to temperature using the Steinhart-Hart equation in 2.4.

$$T = \frac{1}{A + B(LnRs) + C(LnRs)^3) - 273.15} \tag{2.4}$$

- T = temperature returned in °C
- A, B, C = coefficients provided by the thermistor manufacteur

2.2.2 Temperature/Humidity - Campbell Scientific CS215

Function

To complete the monitoring of the conditions inside the BGC-FTIR-Container the digital Temperature/Humidity Sensor CS215 comes into operation. Figure 2.16 shows the sensor. It features a digital SDI-12 output allowing simple connection to the Control-Port of the Datalogger CR1000.

Figure 2.16: Campbell Scientific CS215
[Manual - CS215 Temperature & Relative Humidity Probe, 3/08]

The BGC-FTIR-Container is constructed to have two rooms, a main room where the FTIR instrumentation is fitted and a secondary room with a built-in air conditioning, a fuse box and additionally the control unit. Two digital CS215 observe temperature and humidity in both rooms in order to control air conditions and further on to avoid high humidity levels by providing data to control the air condition.

Measuring Principle

The core of this sensor is a specially developed, patented semiconductor chip, also known as "computer chip". Special sensing structures are implemented on the chip by means of micro systems engineering. They detect precisely and reliably the desired physical parameters, in that case relative humidity and temperature. The fusion of sensor and evaluation circuitry on one chip named CMOS guarantees that the sensitive, analog sensor signals can be amplified and digitized without noise and with high precision. The scheme of this chip can be found in Fig. 2.17.

In addition to the resistive method for temperature measurement, the capacitive measurement principle is used as in the KPC 1/6-ME temperature and humidity sensor. For this principle, the sensor element is built out of a capacitor. The dielectric is a polymer which absorbs or releases water proportionally to the relative environmental humidity, and thus changes the capacitance of the capacitor. This change in capacitance can be measured by an electronic circuit. This allows the relative air humidity to be determined.
The sensor element itself is just as important for the sensor as the directly integrated evaluation circuitry. It is the standard technology for integrated circuit fabrication and the temperature sensor and the humidity sensor form one single unit together.

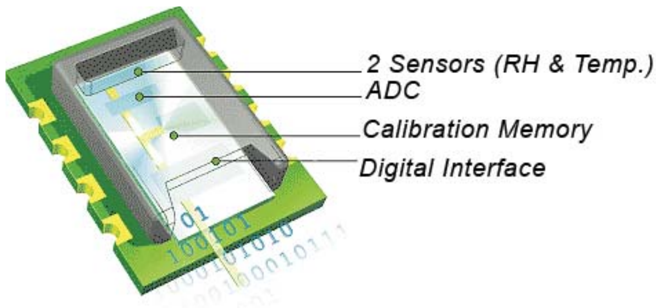


Figure 2.17: CMOSens Chip [http://www.sensirion.com/en/images/CAD_SHT11.gif, 20.10.08]

This sensor includes a temperature sensor that is used for exact temperature compensation. CMOSens sensors also contain additional intelligence on the chip for functional control of the sensor element, for low-power functions, and also for complete linearization and temperature compensation.

Chapter 3

Data Acquisition

3.1 Datalogger CR1000

The following notes give an outline of the ports and moduls which are used for operating with the instrumentation of the automatic weather station. Figure 3.1 gives an overview of several possibilities of connecting sensors and modules to the data logger.

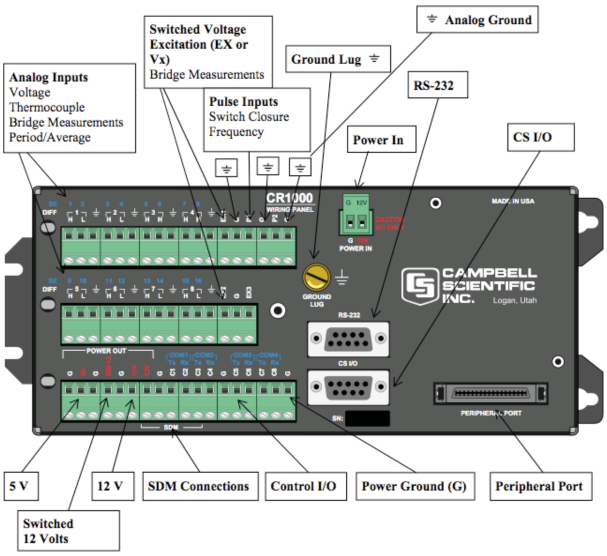


Figure 3.1: Datalogger CR1000
[Manual - CR1000 Measurement & Control System, 1/08]

3.1.1 Connecting Panel

The Datalogger CR1000 has powerful analog and digital features as well as a lot of connection options for communication with several peripherals and sensors. That makes it easy to assemble the weather station with all the instrumentation and additional moduls which are necessary to put a completely autonomous system into practice.

Analog and Switched Voltage

The Temperature/Humidity Sensor KPC 1/6 ME and the Pyranometer CMP3 transmit analog voltage which is measured at the DIFF-Ports of the Datalogger CR1000. Figure 3.2 shows the common connection scheme.

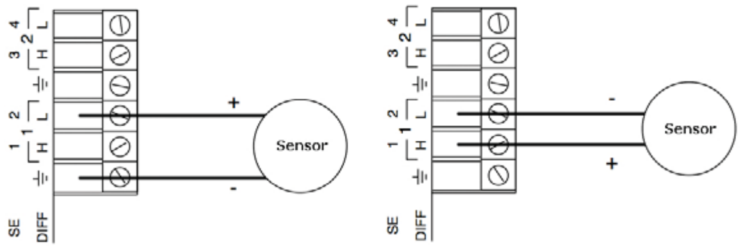


Figure 3.2: Connecting to SE- and DIFF-Ports
[Manual - CR1000 Measurement & Control System, 1/08]

Lambrechts Wind Speed 14557 transmits analog current. This signal is also measured at the DIFF-Ports of the Datalogger CR1000 but has to be transformed into analog voltage by using a high-precision shunt resistor of 100 Ohm. The Temperature Probe T107 has to be excited by the EX-Port because of switched voltage and is measured at the SE-Ports.

Serial Data

The digital pressure sensor PTB210 transmits serial data which are received at the COM-Ports of the Datalogger CR1000. Figure 3.3 shows the common connection scheme.

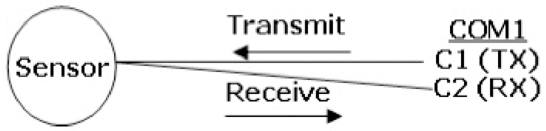


Figure 3.3: Connecting to COM-Ports
[Manual - CR1000 Measurement & Control System, 1/08]

The operating command is send through the transmit line (TX) while the receive line (RX) is responsible for the data acquisition.

SDI-12

Campbell Scientifics Temperature/Humidity Sensor CS215 features a digital SDI-12 output (Serial Data Interface at 1200 Baud). It allows simple connection to the Control-Ports of the Datalogger CR1000 according to Fig. 3.4.

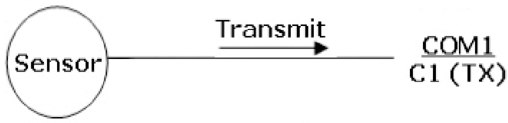


Figure 3.4: Connecting to Control-Ports
[Manual - CR1000 Measurement & Control System, 1/08]

Figure 3.4 shows the common connection sheme. Only the transmit lines (TX) can be used to operate with the SDI-12 sensor output, because communication is achieved by digital communications along a single serial line.

CS I/O

The 9-pin CS I/O-Port (Campbell Scientific Input / Output) as shown in Fig. 3.5 is used to connect to Campbell Scientific telecommuinication peripherals.

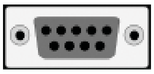


Figure 3.5: CS I/O Port
[Manual - CR1000 Measurement & Control System, 1/08]

It is designed to operate and set-up the Datalogger CR1000 by using the additional keyboard display CR1000KD.

Peripheral Port

To have the alternative of saving data to a CF-Card and operate through a ethernet line the Datalogger CR1000 is equipped with the Ethernet/CompactFlash Module NL115. It is connected to the 40-pin peripheral port on the CR1000 as shown in Fig. 3.6.

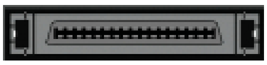


Figure 3.6: Peripheral Port
[Manual CR1000 - Measurement & Control System, 1/08]

3.1.2 Peripheral Devices

Communication with the master host has to be as comfortable as possible due to the flexible and worldwide use of the BGC-FTIR-Container. Moreover, the set-up of parameters concerning the programming or communication should be easy to handle in case of changes or maintenance. Thus, additional modules come into operation.

Keyboard Display - CR1000KD

The idea is to monitor the readings of the weather station as well as to have changes of parameters without the need to connect to a laptop. An optimal solution to achieve that is the additional keybord display CR1000KD as shown in Fig. 3.7.

Figure 3.7: Keyboard Display CR1000KD
[Manual - CR1000 Measurement & Control System, 1/08]

You can have access to the file system on the CPU of the data logger as well as on the CF Card. It is possible to check data and to run and stop a program. You can look up the ports and the status and have the possibility to modify the configuration and the settings of the logger. Detailed information can be found in [16].

Ethernet and CompactFlash Modul NL115

Figure 3.8 shows Campbell Scientific's NL115 Ethernet/CompactFlash Module. It provides two useful capabilities. It enables 10baseT Ethernet communications and stores data on a removable CF-Card. So it is possible to communicate over the local network of the BGC-FTIR-Container, respectively via TCP/IP.

Figure 3.8: Ethernet and CompactFlash Module - NL115
[Manual - NL115 Ethernet & CompactFlash Module, 4/08]

More important is the use of data transfer via FTP. The calibration factors and constants which transform the signals into real units are stored on the CF-Card for further processes by including them within the program run on the CPU. This makes it possible to modify them without a need to access the main program on the CPU. Besides there is a web site of the logger which provides its actual readings and status. In order to have a look at it you simply have to connect with a standard browser. Detailed informations can be found in [16].

Chapter 4

Programming

The CR1000 requires a program be sent to its memory to direct measurement, processing and data storage options. Programs are sent with a special support software but can also be sent from a CF card by using the power-up funtion. For details see section 4.6 on page 51. CR1000 application programs are written in a variation of BASIC (Beginner's All-purpose Symbolic Instruction Code) computer language, CRBASIC (Camp. Recorder BASIC). CRBASIC Editor is a text editor that facilitates creation and modification of the ASCII text file which constitutes the CR1000 application program.
The fundamental elements of CRBASIC are the variables, constants, common instructions and special instructions.

4.1 Outlook

The data acquisition of the instrumentation of the weather station has to be very specific with user-defined declarations in view of variables, constants and instructions in order to get all the necessarry data for implementing the automatic measurement cycle of BGC-FTIR-Container. This includes communication among sensors and ports of the data logger, data storage and measuring loops which are illustrated like followed in this chapter.

4.2 Structure

The proper structure of an CRBASIC program is demontrated in Fig. 4.1 and reflects the general structure of the program written for the automatic weather station.

```
'Declarations

'Define constants
Const RevDiff=1
Const Del=0 'default
Const Integ=250                                  Declare constants
Const Mult=1
Const Offset=0

'Define public variables
Public RefTemp
Public TC(6)
                                                 Declare public variables,
'Define units                                    dimension array, and            Declarations
Units RefTemp=degC                               declare units.
Units TC=DegC

'Define data tables
DataTable (Temp,1,2000)
     DataInterval (0,10,min,10)
     Average (1,RefTemp,FP2,0)                   Define Data Table
     Average (6,TC(),FP2,0)
EndTable

'Begin Program
BeginProg

'Set scan interval
     Scan (1,Sec,3,0)

'Measurements
     PanelTemp (RefTemp, 250)                                                          Measure
     TCDiff (TC(),6,mV2_5C ,1,TypeT,RefTemp,RevDiff,Del,Integ,Mult,Offset)

'Processing (None)                                                                             Scan loop

'Call data table
     CallTable Temp                    Call Data Table

'Initiate controls (None)

'Loop to next scan
     NextScan

'End Program
End Prog
```

Figure 4.1: Proper Program Structure
[Manual - CR1000 Measurement & Control System, 1/08]

4.3 Declarations

The declarations at the beginning of an CRBASIC program are like an abstract for the user to know about the parameters of capital importance. This enfoldes the sensors with their port-usage at the data logger, peripheral devices, both measurement and data storge characteristics. However, this program segment has nothing to do with the actual program run and just gives an account of readings and terms.

4.3.1 Variables and Arrays

A variable is a packet of memory, given an alphanumeric name, through which measurements and processing results pass during the program execution. Variables are declared either as PUBLIC, ALIAS or DIM at the discretion of the programmer. PUBLIC and ALIAS variables can be viewed through the CR1000KD or software numeric monitors. DIM variables cannot but are not to be used for programming the instrumentation of the weather station. The amount of variables depends on the number of sensors and calculation processes which are to be done. First of all, every sensor gets his own variable. If there are any calculations in the runtime of the main scan, this result has to be assigned to annother variable. For example the variables for the counter of measured data per interval are expressed as following:

```
Public N
Public Count
```

When a variable is declared, several variables of the same root name can also be declared. This is done by adding a suffix of "(x)" to the alphanumeric name, wich creates an array of x number of variables that differ only by the incrementing number in the suffix. For example, rather than declaring some similar variables as follows,

```
Public T107_C_1
Public T107_C_2
Public TRHData_1
Public TRHData_2
Alias TRHData_1=TempC
Alias TRHData_2=HumidC
```

it is simply declared as array as shown below:

```
Public T107_C(2)
Public TRHData(2)
Alias TRHData(1)=Temp_C
Alias TRHData(2)=Humid_C
```

This creates in memory four variables T107_C(1), T107_C(2), Temp_C and Humid_C. Thus, the amount of required code reduces to a minimum. Furthermore, this example demonstrates the use of aliases which is equivalent to the assignment of stored ASCII data within the TRHData-Array to the variables Temp_C and Humid_C. The procedure of declaration is repeated to name every sensor and calculating process with its own variable for further output and storage.

Data Types and Operational Detail

Variables and stored data can be configured with various data types to optimize program execution and memory usage. Table 4.1 gives an outline of the used data types.

Code	Data Format	Where Used	Word Size	Range	Resolution
FP2	Campbell Scientific Floating Point	Output Data Storage Only	2 bytes	±7999	13 bits (about 4 digits)
IEEE4 or FLOAT	IEEE 4 Byte Floating Point	Output Data Storage / Variables	4 bytes	±1.4 x 10^{-45} to ±3.4 x 10^{38}	24 bits (about 7 digits)
STRING	ASCII String	Output Data Storage / Variables	Set by program		

Table 4.1: Details of used Data Types
[Manual - CR1000 Measurement & Control System, 1/08]

The declaration of variables via PUBLIC or DIM statement allows an optional type descriptor AS that specifies the data type. The default data type, without a description, is IEEE4 floating point (FLOAT).

Variable data types are STRING and the numeric types: FLOAT, LONG and BOOLEAN. In the program sequence of the automatic weather station the data types IEEE4 an STRING are to be used. The example below points this out.

```
Public T107_C(2)
Public AirPressString AS STRING * 30
```

In this case the T107_C(2) variable is a simple array of two temperature measurements with IEEE4 standard as data type where the STRING data type is put in because of the need to transmit simple text commands through a serial line for operating the digital pressure sensor PTB210. As a result serial data are received in terms of pressure readings at a individual configured port of the data logger. The numeric expression *30 represents the maximum of text characters to be sent depending on the length of the required command.

Units

Every variable stored in the tables is assigned to its engineering unit as shown below.

```
Units Temp_C = Deg C
Units Humid_C =  %
Units WindSpd = m/s
Units Pyrano = W/m^2
Units AirPress = hPa
```

Thus, it is easier to handle data for future interpretations or calculations for people who do not know about the source code of storage process. Units are strictly for documentation. The CR1000 makes neither use of them nor checks on their accuracy.

Constants

A constant can be declared at the beginning of a program to assign an alphanumeric name to be used in place of a value so the program can refer to the name rather than the value itself. Using a constant in place of a value can make the program easier to be read and to be modify and more secure against unintended changes.

In the programming of the weather station all constants such as calibraiton factors, offsets and ASCII text commands are stored in an external data file on the CF card. For detailed information of source code see appendix B on page 85. It is itegrated within the normal program sequence through a simple include command for execution. The example below shows the procedure of declaring constants.

```
Const = CR = CHR(13)
Const = LF = CHR(10)
Const = Command = ".P" + CR + LF

Const = wind_multiplier = 0.03125
Const = wind_offset = -12.5
```

The first part distinguishes the combination of commands like carriage return CHR(13) and line feed CHR(10) with operating commands to a single instruction named "Command". The characters were taken from the library of CRBASIC. This instruction can be sent through a serial line to operate sensors, in this case, the digital PTB210 barometers from Vaisala.
Every analog sensors uses its proper multiplier and offset for converting the analog voltage into real units like demonstrated. For details see section 4.5.1 on page 49.

4.4 Data Tables

Data are stored in tables as directed by the CR1000's CRBASIC program. A data table is created by a series of CRBASIC instructions which are entered after variable declarations but before the main program. These intructions include:

```
DataTable() / EndTable
Output Trigger Condition(s)
Output Processing Instrucions
EndTable Instruction
```

A data table is essentially a file resides in CR1000 memory. The file is written to each time data are directed to that file.

The program stores individual measurements as minimum, maximum, squared sum and averages as base values for a scan interval in two different tables for outdoor and indoor measurements. Moreover each table is associated with overhead information that becomes part of the ASCII file header when data are downloaded to a PC. This header includes:

- table format
- datalogger type and operating system version
- name of CRBASIC program running in the datalogger
- name of data table
- alphanumeric field names to attach at the head of data columns

A typical data table after downloading or after converting the binary file can be viewed like shown in Table 4.2.

TOA5	CR1000	CR1000	1048	CR1000.Std.13.06	CPU:Data.CR1	35723	OneMin
TIMESTAMP	RECORD	Batt_Volt_Avg	PTemp_C_Avg	Temp_C_Avg(1)	Temp_C_Avg(2)		
TS	RN	Volts	Deg C	Deg C	Deg C		
		Avg	Avg	Avg	Avg		
7/11/2007 16:10	0	13.18	23.5	23.54	25.12		
7/11/2007 16:20	1	13.18	23.5	23.54	25.51		
7/11/2007 16:30	2	13.19	23.51	23.05	25.73		
7/11/2007 16:40	3	13.19	23.54	23.61	25.95		
7/11/2007 16:50	4	13.19	23.55	23.09	26.05		
7/11/2007 17:00	5	13.19	23.55	23.05	26.05		
7/11/2007 17:10	6	13.18	23.55	23.06	25.04		

Table 4.2: Typical Data Table
[Manual - CR1000 Measurement & Control System, 1/08]

4.4.1 DataTable() and EndTable()

As already shown, data table declartion begins with the DataTable() instruction and ends with the EndTable instruction.

```
DataTable(Table_Indoor,True,-1)
...
EndTable
```

Between these instructions that define what data are to store and under what conditions data are stored. A data table must be called by the CRBASIC program for data storage processing to occur. Typically, data tables are called by the CallTable() instruction once each scan in the main program.

The DataTable instruction has three parameters:

- Name - name of data table up to 20 characters
- TrigVar - trigger conditions true or false
- Size - table size is set to a fixed number of records or to autoallocate function

In that case the table name is Table_Indoor with a trigger variabel set to true to run the table and a size set to automatically allocated memory limit by using the expression -1.

4.4.2 DataInterval()

DataInterval() sets the period in which data are stored. It has four parameters:

- TintInt - time into interval for offest
- Interval - how often data will be stored
- Units - specify units on which the TintInt and Interval argument will be based
- Lapses - number of lapses or gaps in the interval to track

A timestamp will not be stored for each record. When data are downloaded or the binary fomat is converted by the support software, timestamps are calculated from the data storage interval set in DataInterval() and the time of most recent record. As each new record is stored, the current timestamp is compared with the last known stored record. So when the CR1000 determines a record has been skipped, a timestamp will be stored with the data. This discontinuity in records is termed a "lapse". The DateInterval() for the tables of the weather station is set as followed:

```
DataInterval(0,60,Sec,10)
```

Thus, data are stored without an offset once a minute as defined and retains the most recent records in RAM up to an automatically allocated memory limit. The lapse parameter is set to 10 and characterizes the maximum number of lapse time stamps that will be recored and allocates the additional memory space required for the lapse time stamps.

4.4.3 Output Processing Instructions

Data storage processing instructions determine what data are stored in the data table. When a data table is called in the CRBASIC program, data storage processing instructions process the defined variables holding current inputs or calculations. However, the process of data storage to the CF card can be implemented. The data table for indoor monitoring looks as following:

```
DataTable(Table_Indoor,True,-1)
DataInterval(0,60,Sec,10)
CardOut(1,-1000)
Average(2,T107_C(1),FP2,Fasle)
Average(1,Temp_C,FP2,False)
Average(1,Humid_C,FP2,False)
Sample(1,N,FP2)
EndTable
```

Both data of temperature and humidity are stored without an offset once a minute as defined average and the number of records during the main scan interval is stored in the associated variable N. Furthermore the common output is carried forward to the CF card and saved in fill and stop mode in data tables.

Average, Sample and CardOut are predefined instructions within the library of CR-BASIC. The following notes give an account of the crucial instruction parameters which are of great importance for the storage process.

The CardOut instruction has 2 parameters:

- StopRing - parameter 0 (Ring Mode) or 1 (Fill and Stop Mode)
- Size - fixed number of records, autoallocate (-1) or same size like in memory (-1000)

The Average instruction has 4 parameters:

- Reps - number of elemets in the variable array for which to calculate the averages
- Source - name of the variable for which an an average should be saved
- DataType - select the format in which an average should be saved
- DisableVar - variable used to determine, weather the current measurement is included in the average saved to the data table (False = process current measurement)

The Sample instruction has 3 parameters:

- Reps - number of samples to store to the data table
- Source - name of variable for which a sample should be saved
- DataType - selects the format in which to save the data

Once the instruction commands and paramters are determined they can be applied in the same way to the storage process of the other sensor's output.

The data table of outdoor measurements looks more comprehensive because of the redundant sensor principle. Moreover are there further parameters (minimum, maximum, squared sum) which have to be recorded. An abstract of the outdoor data table with its recording process for wind speed looks as follows:

```
DataTable(Table_Outdoor,True,-1)
DataInterval(0,60,Sec,10)
CardOut(1,-1000)
Average(2,WindSpd(1),FP2,False)
Minimum(2,WindSpd(1),FP2,False,False)
Maximum(2,WindSpd(1),FP2,False,False)
Totalize(1,WindSpd_SQ_1,IEEE4,False)
Totalize(1,WindSpd_SQ_2,IEEE4,False)
Sample(1,N,FP2)
EndTable
```

The totalize instruction is to add up the squared records within the time interval. In association with the number of measured data N scaned by the Sample instruction, you can have calculations concerning the standard deviation.
The Minimum and Maxiumum instruction contains an additional parameter "Time" which determines, weather the time that the minimum or maximum value occurred should be stored. In this case, it should not be stored.
Thus, wind speed is recorded once a minute. Data types are FP2 for fundamental values (average, minimum, maximum) and IEEE4 for squared sum because of greater recording results and consequently the necessity of greater memory usage. The variable N is stored as number associated with the counter of measured data per interval. Instructions for the other senors are equivalent to that and can be looked up in the appendix section A on page 79.

4.5 Program - Main Scan

Aside from declarations and tables the CRBASIC program needs more instructions in order to work properly and above all instructions to assign the variables with the intended values. The executable code begins with BeginProg and ends with EndProg.

Measurements, processing and calls to data tables within the Scan / NextScan loop determine the sequence and timing of program functions.

```
BeginProg
Scan(5,Sec,0,0)
Therm107(T107_C(1),2,1,Vx1,0,_50Hz,1,0)
Count = Count + 1
N = Count
If TimeIntoInterval(0,60,sec) Then
Count = 0
EndIf
CallTable(Table_Indoor)
NextScan
EndProg
```

This simple example represent a temperature reading of two temperature values out of the T107_C-Array and its assignement to the variabels T107_C(1) and T107_C(2). The records will be called to the data table Table_Indoor as well as the number of measured data N within a scan loop of 5 seconds. An average of 12 values and the number of measured data per interval is to be saved every minute according to the declarations for the data tables .

The scan intruction has an interval parameter for setting the interval between scans, a units parameter for which this interval is based on and some buffer and counter options which are set to false, because no scan has to be hold in RAM and the scan should continue looping forever.

The counter is a simple incrementing number assigned to the varibale N within the scan loop. It is set to zero after a time into interval of 60 seconds.

4.5.1 Instructions

In addition to BASIC syntax, additional intructions are included in CRBASIC to facilitate measurements and store data like shown in in the previous example. The following notes give an outline of the use of some instructions for operating the instrumentation of the automatic weather station.

Port-Configuration and Measurement Processing

First of all it is of great importance to define the ports on which the sensors should work. A distinction is drawn between the analog sensors, whose signals are picked off at the SE- and DIFF-Ports and the serial sensors whose data comes in at the COM- and C-Ports of the data logger.
The analog sensors featuring differential measuremnts are picked off as following:

```
VoltDiff(Temp(1),2,mV2500,7,True,0,_50Hz,temp_multiplier,temp_offset)
```

This instruction measures the voltage difference between the high and low inputs of a differential channel, starting at DIFF-Port 7, ending at DIFF-Port 8 because of temperature array which includes two temperature measurements of two differernt sensors. Both the high and low inputs must be within +/- 5 V of the data loggers common range. By including its multiplier and offset, the voltage output is converted into the engineering unit °C at the same time.
However, there are also predefined intructions for frequently used sensors with analog output as for example Campbell Scientifics T107.

```
Therm107(T107_C(1),2,1,Vx1,0,_50Hz,1,0)
```

In this case two temperature readings at SE-Port 1 and 2 are done with an output in °C.

Serial sensors are not as easy to handle. The following example of pressure readings illustrates this issue.
First you have to set up the datalogger's ports for communication with a non-PakBus device.

```
SerialOpen(Com1,9600,10,0,0)
SerialOpen(Com2,9600,10,0,0)
```

When the serial open function is executed, the serial ports are "opened" at 9600 baud and subsequent textual messages will flow in and out of the port in between PakBus packetes. The format parameter "10" specifies the type of error detection to be used for the exchange of data. "10" equates the manufacturers' instructions of an RS232 logic type, even parity, one stop bit and 7 data bits for communication with Vaisalas PTB210 barometer.
Accordingly serial text messages have to be transmitted through the serial lines for operating the digital sensors.

```
SerialOut(Com1,Command,"",0,100)
SerialOut(Com2,Command,"",0,100)
```

Thus, the as constant defined "Command" is sent to both sensors including the necessary parameters for operation, ".P", carriage return <cr> and line feed <lf>. As a result serial data of both sensors in form of pressure readings in hPa is received within the AirPress-Array as follows:

```
SerialIn(AirPress(1),Com1,100,10,10)
SerialIn(AirPress(2),Com2,100,10,10)
```

The acquired information of port configuration and measuring processing can be brought forward to handle all the other sensors. For details see the appendix section A on page 79.

Calibration Factors and Offsets

Calibration factors and offsets are important parameters which have to be determined for converting analog signals into engineering units. The parameters are calculated due to the voltage output ranges referring to their output range for metorological data according to a simple equation system:

$$xU(V)_l - y = z_l \tag{4.1}$$

$$xU(V)_u - y = z_u \tag{4.2}$$

- $U(V)_l$ = voltage output for the lower bound of measurement range
- $U(V)_u$ = voltage output for the upper bound of measurement range
- z_l = lower bound of measurement range
- z_u = upper bound of measurement range
- x = multiplier
- y = offset

The engineering unit for global solar radiation is calculated with its spectral sensitivity according to equation 2.2 on page 21.

In reference to the manufacturer's data the following parameters in Table 4.3 were calulated, defined as constants and included in the program sequence for converting the outputs.

SENSOR	CALIBRATION FACTOR	OFFSET
KPC 1/6 ME Temp.	0.1	30
KPC 1/6 ME Humid.	0.1	0
14577 Wind Speed	0.03125	12.5
CMP3 Pyranometer	75.13148	0

Table 4.3: Calibration Factors and Offsets

4.5.2 Expressions

Expressions are used as operators or numbers that produce a value or a result. The programming of the automatic weather station requires such expressions in terms of converting strings into numeric values as well as to save a squared sum over the scan interval.

String Expressions

CRBASIC allows the addidtion and concatenation of string variables to variables of all types using + operators. The serial output of the digitlal pressure sensor PTB210 is picked up as string which inevitably leads to problems having calculations with it.

```
AirPressString = AirPress(1) + "," + AirPress(2)
SplitStr(AirPressNum(1),AirPressString,",",2,0)
```

AirPressString is an array of two serial pressure readings which is splited into two equal numeric values assigned to the variables AirPressNum(1) and AirPressNum(2). From now on every kind of mathematical instruction can be executed.

Mathematical and Logical Expressions

Mahtematical operations are written out as if they are algebraically. For example the calculation of the squared value of pressure readings looks like following:

```
AirPress_SQ_1 = AirPressNum(1) * AirPressNum(1)
AirPress_SQ_2 = AirPressNum(2) * AirPressNum(2)
```

The squared sum is defined in the data tables with the following expression:

```
Totalize(1,AirPress_SQ_1,IEEE4,False)
Totalize(1,AirPress_SQ_2,IEEE4,False)
```

This progression is applied to every reading.
A simple logical expression in the form of a counter for measured data perinterval was already given in section 4.5 on page 46.

4.6 User-Defined Power-Up Function

The key to the CF power-up function is the powerup.ini file, which contains a list of command lines. At power-up, the powerup.ini command line is executed prior to compiling the program. The powerup.ini is created with a text editor and the syntax is very simple. Detailed information can be found in [16].

Command,File,Device

The powerup.ini is allways copied to the CF-Card with the associated files for proceeding the action. The default file is:

```
6,WMS_FTIR.CR1,CPU
```

At power-up this file will lead to copy the main program WMS_FTIR.CR1 on the CF-Card to the CPU of the datalogger for running immediately. Data on the CF-Card will be preserved. The new data will be simply added to the old tables if there are no changes in saving of data. Otherwise the data will be stored in new tables. Thus, it is possible to load a new program to the data logger's CPU as well as to change calibration factors in the constant file on the CF card which will be executed after power up without the need to change the main program.

Chapter 5

The Sensors - Test Series

It is a basic need to test the sensors for their functional capability and accuracy in advance. This is also meant to prevent possible differences in readings due to the redundant sensor principle.
The following sections will give an overview of the sensors which have been properly tested. Some of the sensors measuring temperature, humidity and pressure have been tested in the climate and pressure chamber at the Max Planck Institute for Biogeochemie Jena. Wind speed was tested in the air duct of the University of Applied Science Jena. The sensors which are not enumerated were just tested for their operability.

5.1 Climate and Pressure Chamber

5.1.1 Temperature/Humidity - Galltec/Mela KPC 1/6-ME

The compact sensor KPC 1/6-ME has been testet for his operability, accuracy and dynamic behavior in comparisson to a reference device. Additionally booth sensors were compared in order to determine possible differences in the measurement result. Therefor readings in temperature and relative humidity varying according to a programmable logic control were done.

Temperature and Humidity Mesurement as a Function of Time

The base for further interpretations are the time responsed measurements. Figure 5.1 reflects the chronological sequence of temperature in escalated steps of five degrees celsius which was kept within a period of thirty minutes before skipping to the next temperature level.

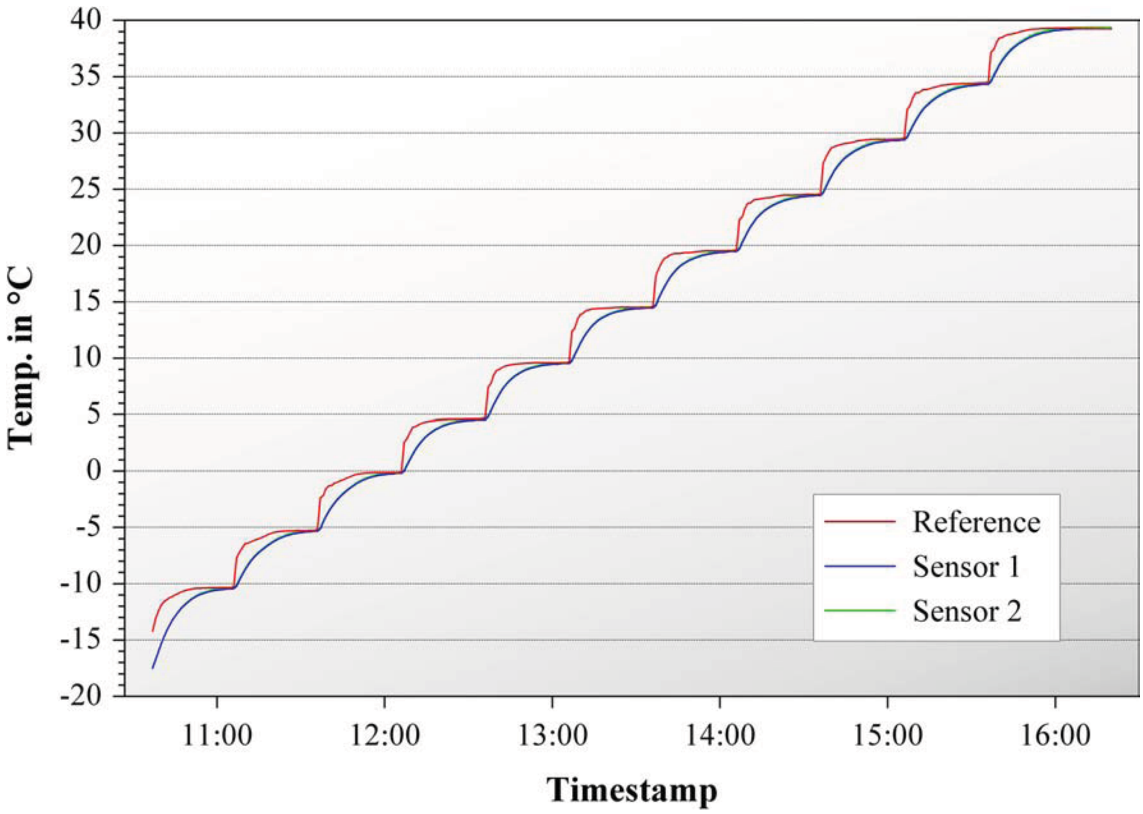


Figure 5.1: Temperature Measurement as a Function of Time

The blue and green line represent the two sensors, whereas the red line expresses the reference device. It is striking that there is almost no difference in readings among the sensors. However, there are varieties in response time in comparison to the reference device. The reason for that is the use of the ZE21-type sintered high-grade steel filter which leads to a change in dynamic behavior because of its fine pored state to protect the sensing element for salt mist.

To verify the humidity readings the programmable logic control was set to escalated steps of five percent which was kept within a period of thirty minutes before skipping to the next level.

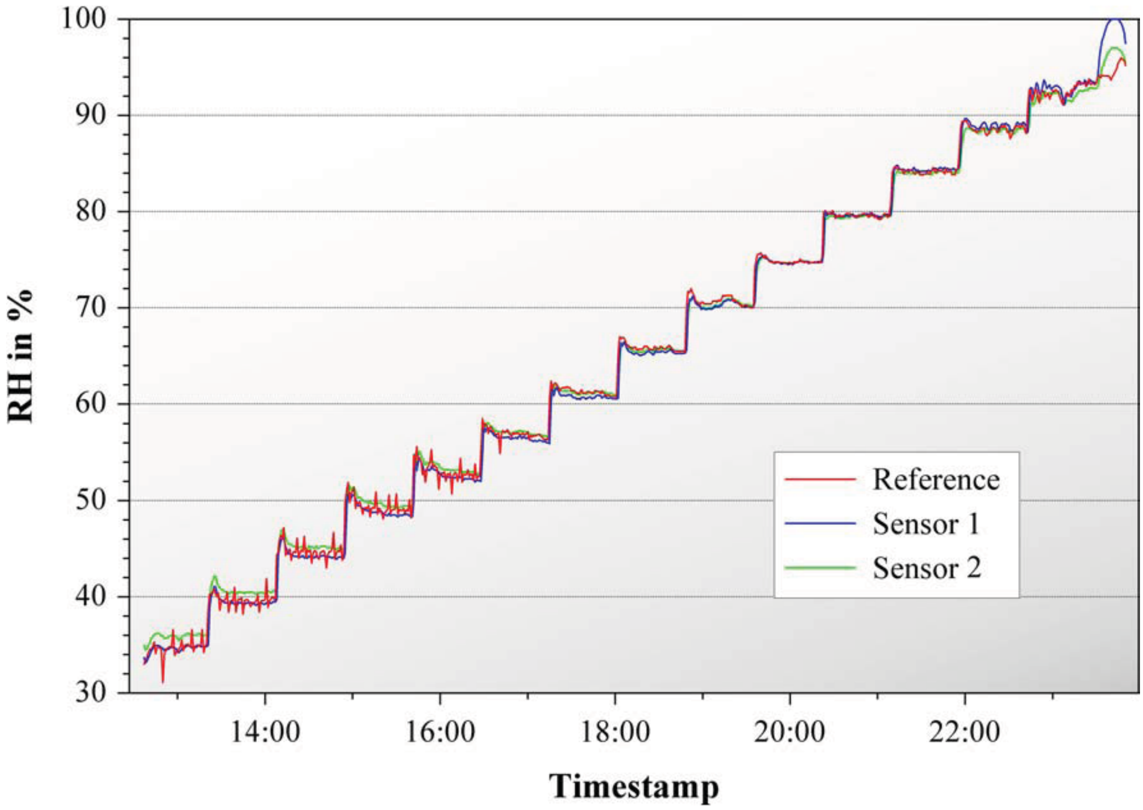


Figure 5.2: RH Measurement as a Function of Time

Figure 5.2 gives an account of the chronological sequence of this measurement.
The curve progression may appear a little bit strange at first sight. The reason for that is as simple as partly preventable. The Dewmet Sensor from Michell Instrumentations is to be used as a reference. It measures humidity with the dew point mirror principle. The mirror is cooled down and normaly should be kept around the barrier of condensation. In this experimental set-up, the reference is placed next to the chambers air flow which makes it almost impossible to keep the temperature of the mirror at the dew point level. This is especially problematic at very low ranges in case of reaching the dew point.

As a result measurements varying according to the process of line-up are recorded. A simple troubleshooting can be accomplished by placing the reference sensor farther to the air flow of the climate chamber. Thus, there are no problems in the lining up of the intended humidity level. Furthermore can there be a filter to smooth the curve progression.

Temperature and Humidity Profile

The profiles demonstrated in Fig. 5.3 point out the differences in response time as a result of the changes in dynamic behaviour because of the filter around the sensing element.

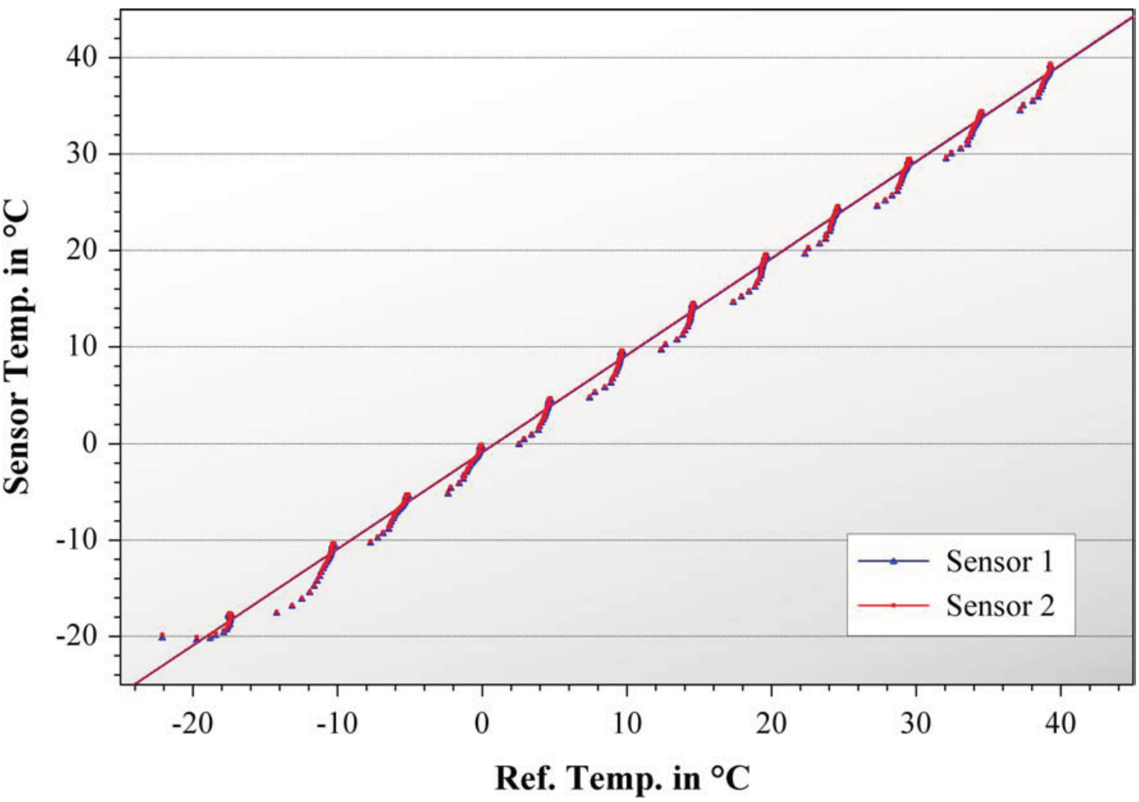


Figure 5.3: Temperature Profile Sensor 1 and Sensor 2

The readings need some time before reaching the same levels which, however, does not affect the reliability of the system and therefore is insignificant.

However, regression shows linear characteristics towards the line-up of booth sensors. Apart from that accuracy amoung the two sensors in temperature reading is well demonstrated, but is to be discussed later in this section.

Figure 5.4 shows the humidity profile of both sensors regarding the reference device of the climate chamber.

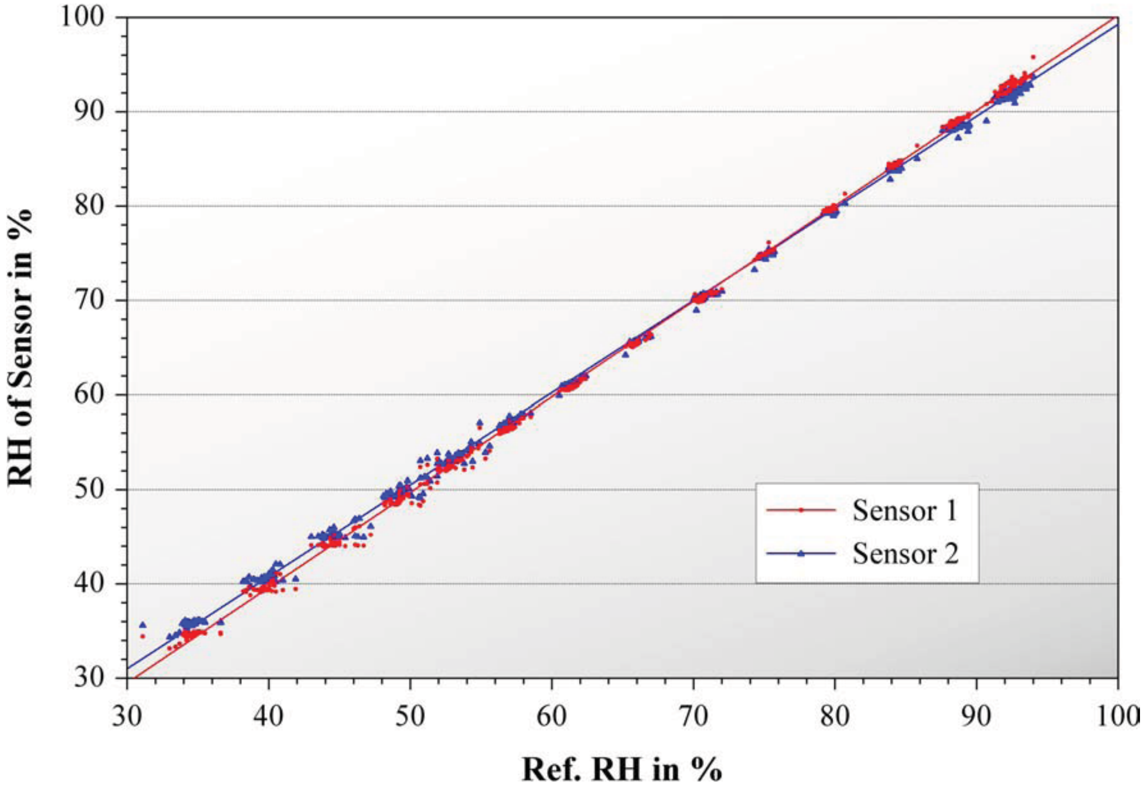


Figure 5.4: RH Profile Sensor 1 and Sensor 2

Both sensors indicate quite linear charactericstics and there are just small variances among the sensors in bands less and greater than 70 % humidity. However, the actual result shows that readings range within the specified measuring tolerance of 2 % humidity.

Sensor Difference for Temperature and Humidity

To have quality assurance concerning the redundant sensor principle, an interesting aspect is to find out possible differences in readings of the sensors. Thus, the sensor difference was calculated which deliberates that accuracy among both sensors has reached no mentionable value.

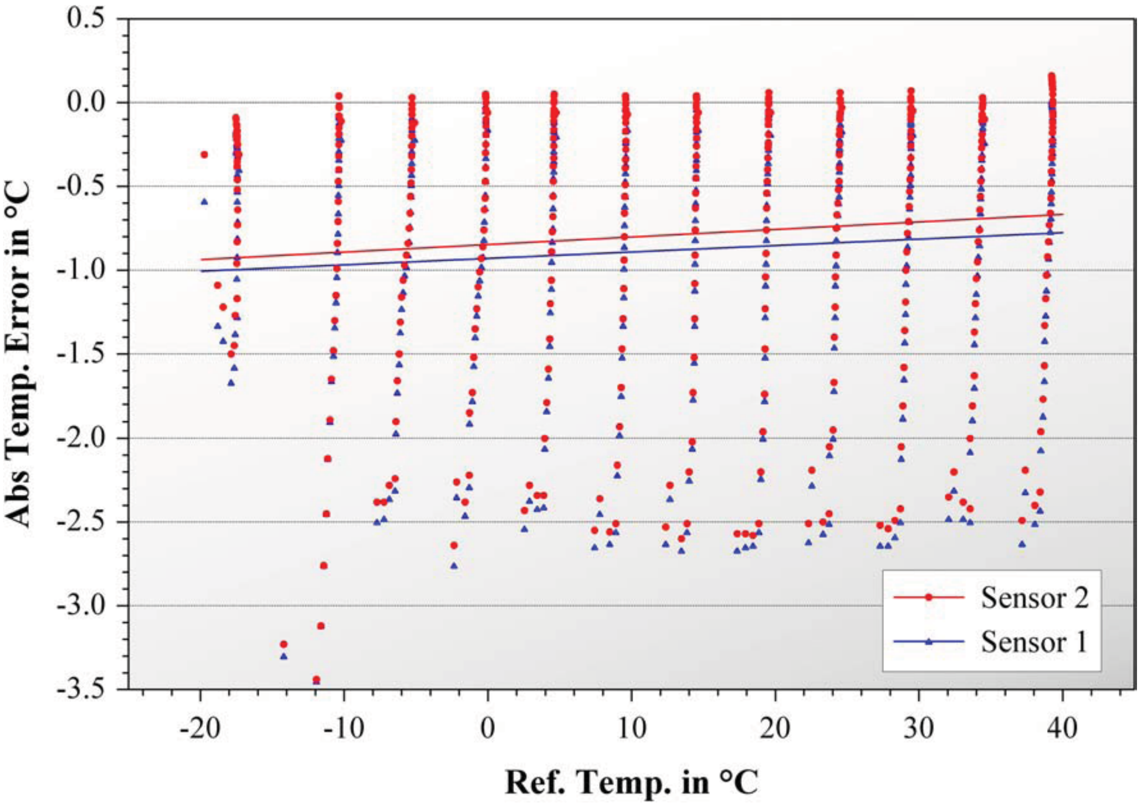


Figure 5.5: Sensor Difference for Temperature

The graph in Fig. 5.5 demonstrates this issue in case of sensor difference concering the temperature reading versus the temperature reference. The inertia due to the filter is also quite nice demonstrated. Anyway, differences in readings show a constant level of about 0.1 °C across the measuring cycle. Offsets are becoming smaler with increasing temperature.

Figure 5.6 points out the sensor difference of humidity with a maximum at 1.4 % humidity. Readings in bands around 70 % humidity show a minimum in variations of recorded measurements among the sensors and also a minimum in variations relating to the reference. The sensors are slightly drifting apart in bands around 70 % humidity. Offsets are decreasing towards ranges around 70 % humidity.

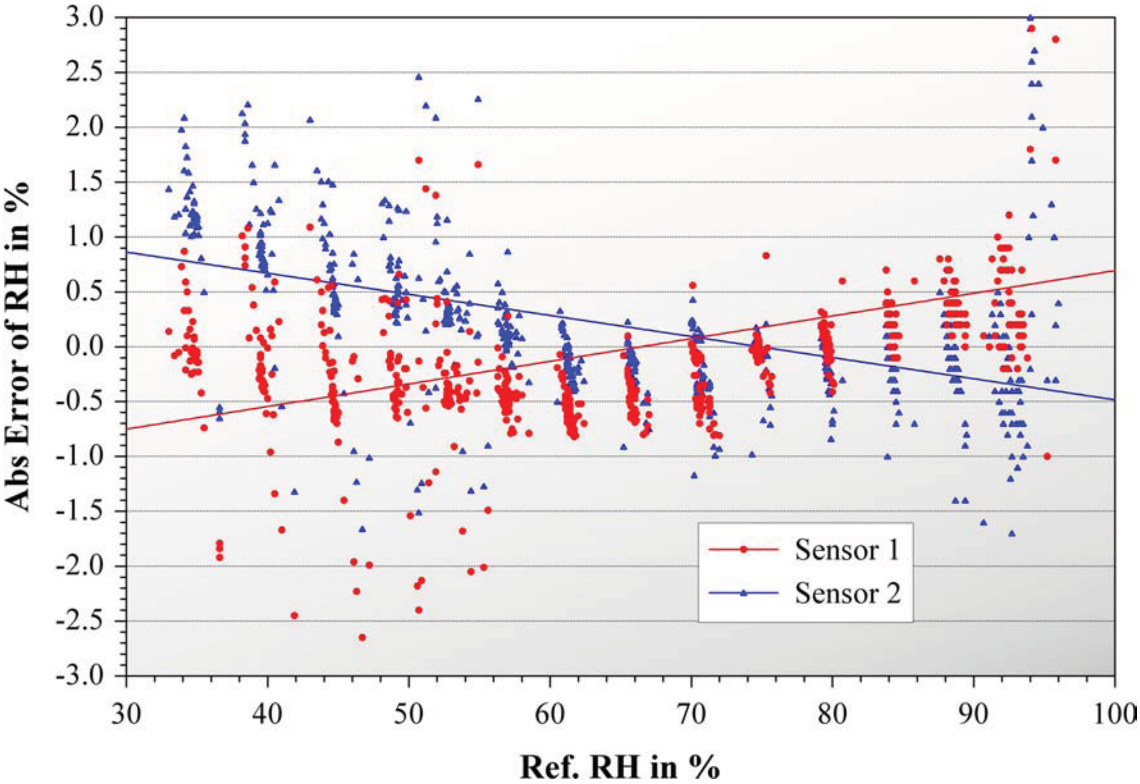


Figure 5.6: Sensor Difference for RH

5.1.2 Pressure - Vaisala PTB210

The PTB210 series barometers offer an excellent solution for outdoor installations with the need for high reliability and accuracy. Nevertheless, the sensors have been tested for their operability, accuracy and dynamic behavior in comparisson to a reference device as well as compared mutual. For this purpose readings within their output range from 500 to 1100 hPa were done. The programmable logic control was set up to steps of 50 hPa within a timeframe of 15 minutes.

Pressure Measurement as a Function of Time

The graph of pressure as a function of time gives an account of the excellent accuracy of the digital barometers from Vaisala.

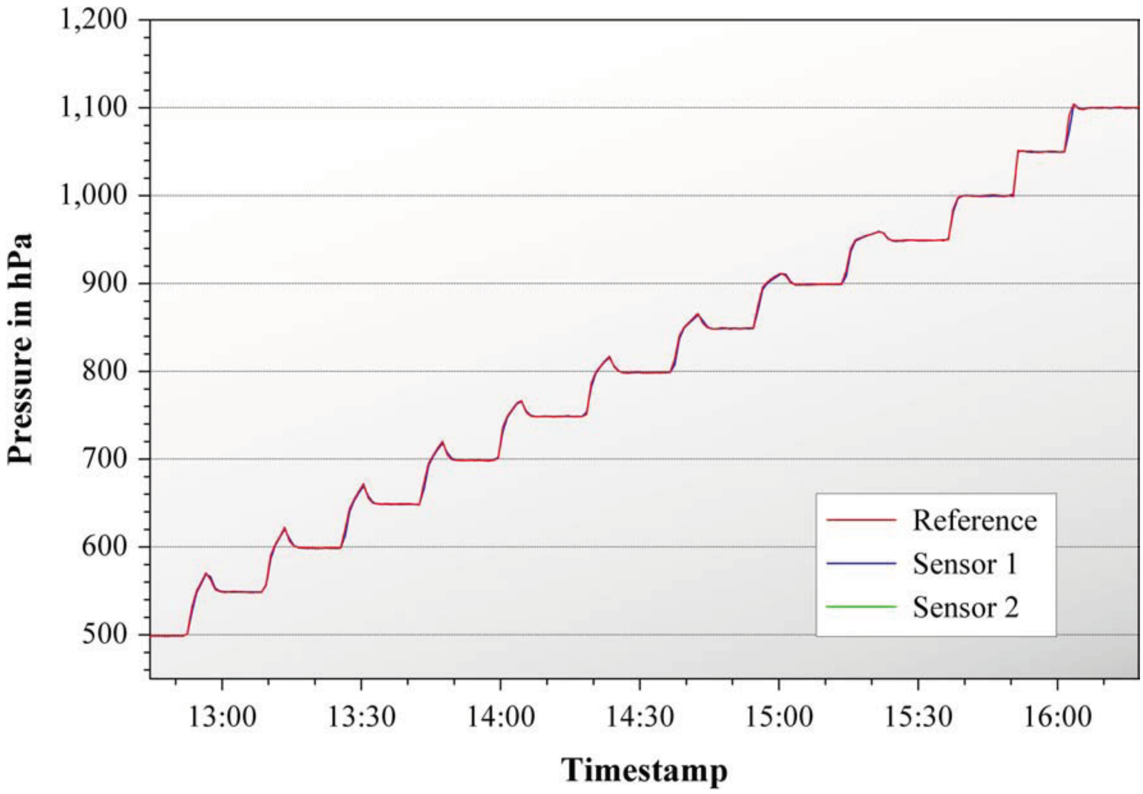


Figure 5.7: Pressure Measurement as a Function of Time

There are almost no variances in pressure readings, neither according to the climate chamber reference device DPI 740 nor to the sensors itself.
The overshooting reflects the process of line-up.

Pressure Profile

Regarding the reference device of the pressure chamber, the profiles of pressure readings show very good linear characteristics in the common measurement range as shown in Fig. 5.8. This, requirements of high accuracy and precision concerning further calculation of mixing ratio can be implemented with this sensors like expected.

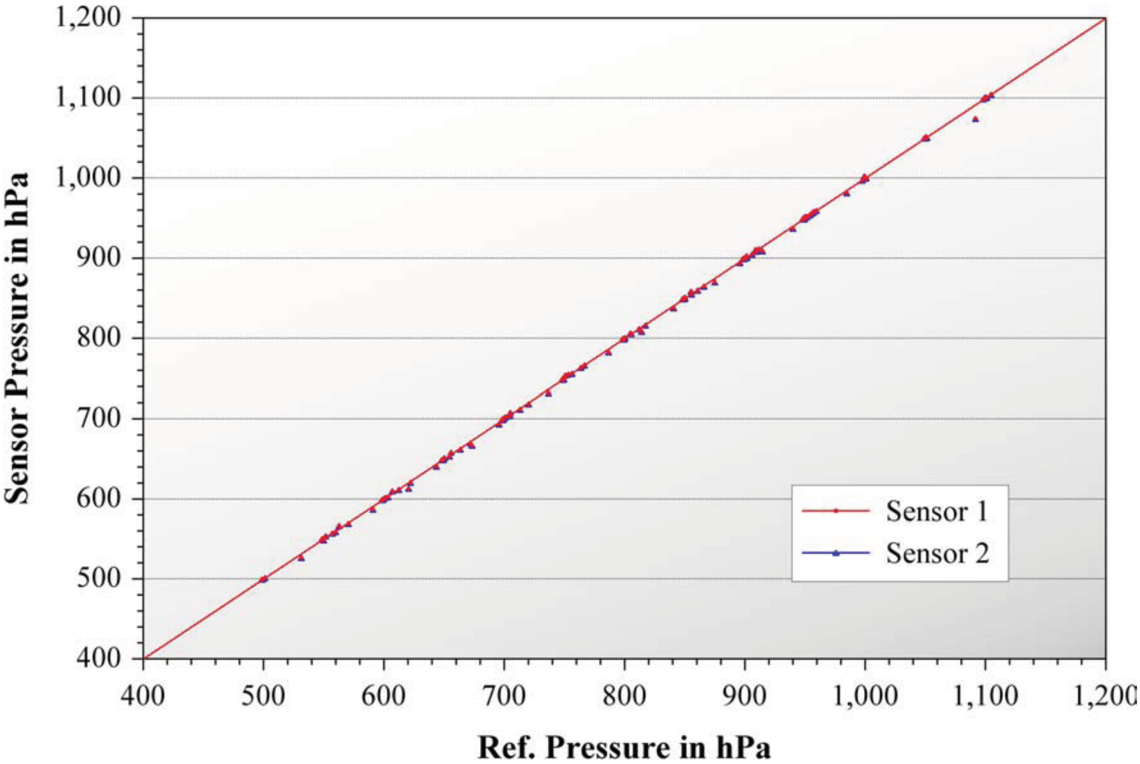


Figure 5.8: Pressure Profile Sensor 1 and Sensor 2

Sensor Difference

The findings in differences of pressure readings among the sensors constrain at a maximum of approximately 0.03 hPa according to Fig. 5.9 and have been found in lower and higher pressure ranges around 500 to 600 and 1100 to 1200 hPa. Ranges around the standard atmospheric pressure show almost no variatons.
Offsets are becoming greater with increasing pressure.

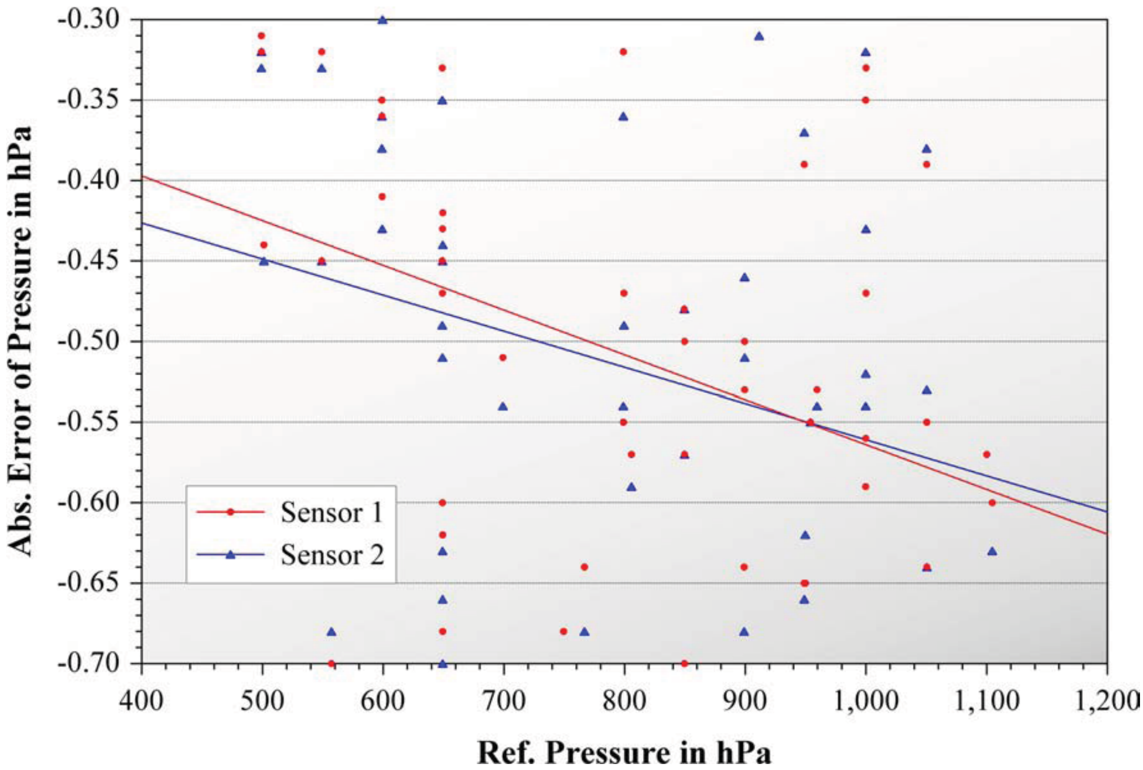


Figure 5.9: Sensor Difference for Pressure

5.2 Air Duct

5.2.1 Wind Speed - Lambrecht 14577

The cup anemometers were tested in escalated steps of 5 m/s, starting at 5 m/s, up to 20 m/s within a timeframe of 10 minutes.
Unfortunately there ocured problems securing the data from the logger for which reason this sections does not cover the evaluations for the measurements.
However, the readings were accurate and have shown no remarkable variations according to the reference device and the sensors.

Chapter 6

Mounting of the Weather Station

6.1 Development of a Wiring Panel

There are a couple of plug connections and interfaces in order to receive accurate signals at the Datalogger CR1000 and the SPS.

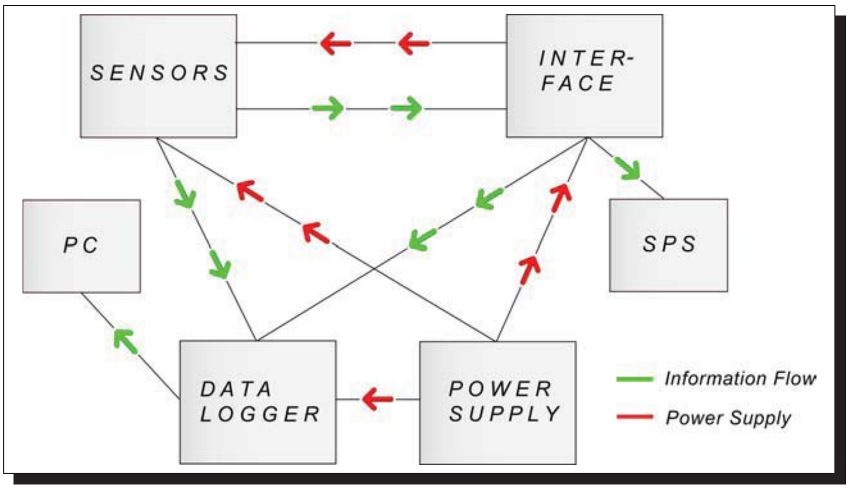


Figure 6.1: Schematic of Information Flow and Power Supply

Figure 6.1 points out the common connection scheme. The green line represents the information flow of the sensors, splited in a direct and in a indirect way. This is because of direct connection among sensors and the data logger inside the container as well as due to signal flows in very low mV ranges, i.e. transmitted by the pyranometer, in order to prevent losses in signal strength.

However, the signals of precipitation detection are directly processed by the SPS where the remaining data is retrieved by the master PC for further processing.
The power supply is also splited which is represented by the red line.

6.2 Mounting

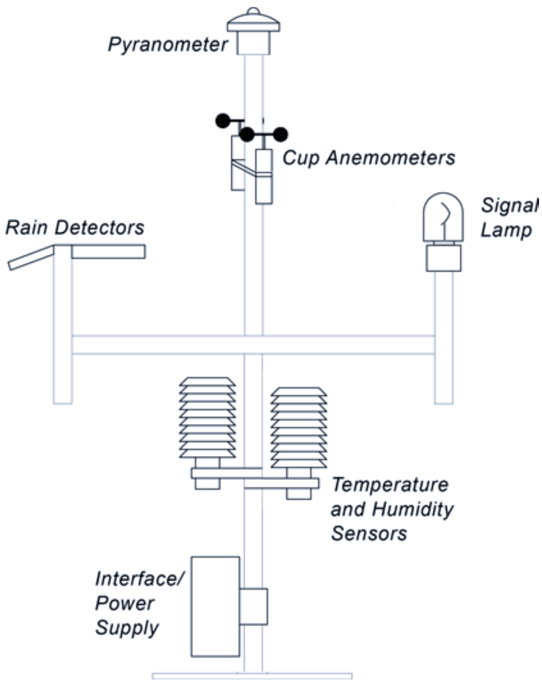


Figure 6.2: Weather Station Mast

There is a need to have an experimantal setup wich is equivalent to the information flow in the container before finally installing all components. Therefore a wiring panel was developed which contains all interfaces and plug connections from the sensor to the logger. A setup according to this plan was done to simulate the operating mode in the BGC-FTIR-Container as well as to verify a proper signal flow. For a detailed wiring plan please see [16].
After a proper test run, the instrumentation of the weather station has to be mounted. For this purpose a mast was installed on top of the container to provide a basis for mounting as shown in Fig. 6.2. Further componets like power

supply, sensors for inside-monitoring and the data logger have been installed inside the container at appropriate places.
Positioning of the pressure sensors is to be more difficult due to the need of high precission. As the sensors are mounted inside, pressure sampling has to be at a windless cavity outside the container. The outside positioning could lead to errors in measuremnts in case of turbulences effecting some pressurization caused by the aerator in the cavity. For that reason some test readings were done.

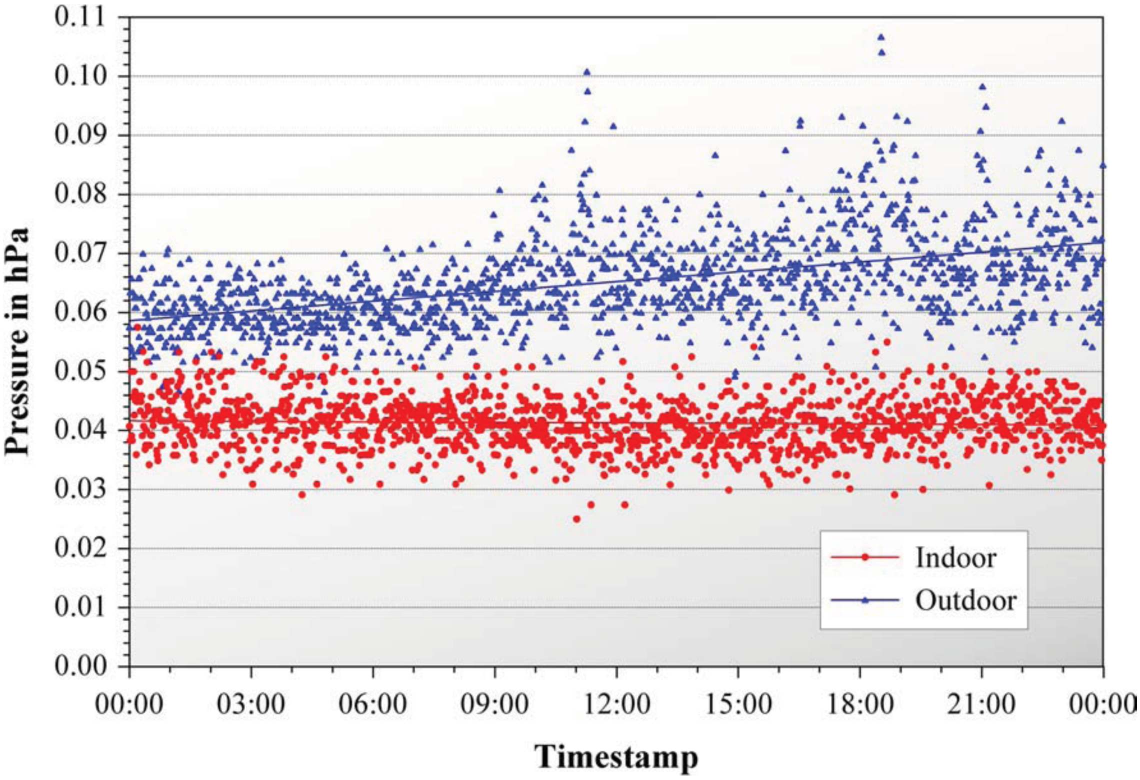


Figure 6.3: Absolute Sensor Difference Indoor and Outdoor

The test readings cover measurements of both sensors, inside and outside the container. These readings were compared and their results of absolute sensor difference are presented in Fig. 6.3.

The offset of both measurements is a consequence of differences in height of the positioning of the sensors. However, there are some measurements in readings varying from the actual sensor difference.

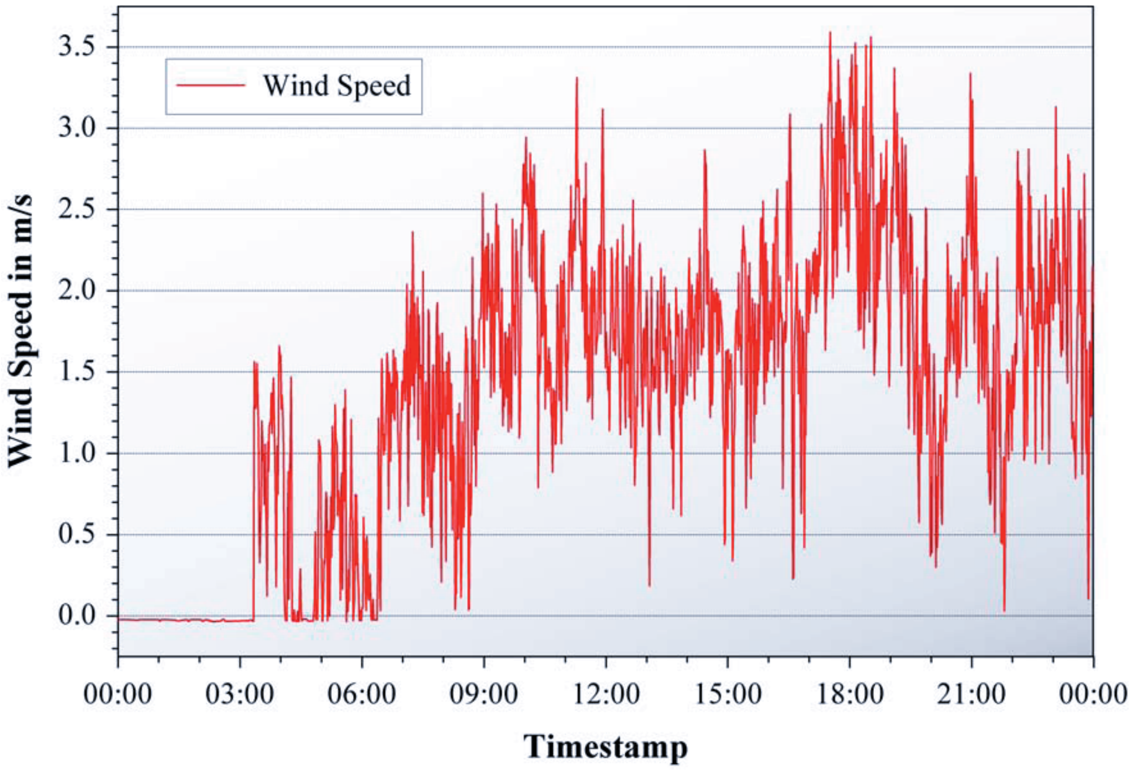


Figure 6.4: Wind Speed

Regarding to wind speed as shown in Fig. 6.4 at that time, the measurements are keenly correlating among each other and give an account for the variant readings from the actual sensor difference. Thus, errors in measuremnts in case of an operating aerator can be excepted.

Chapter 7

Evaluation

Once the hardware has been configured, basic communication over TCP/IP is possible. These functions include sending programs, collecting data and displaying at the most current record from tables. The following notes do demonstrate this functions using TCP/IP for data transfer and displaying latest records. All test were done via the remote mode connecting from the office to the container.

7.1 Test Run

7.1.1 Datalogger Home Page

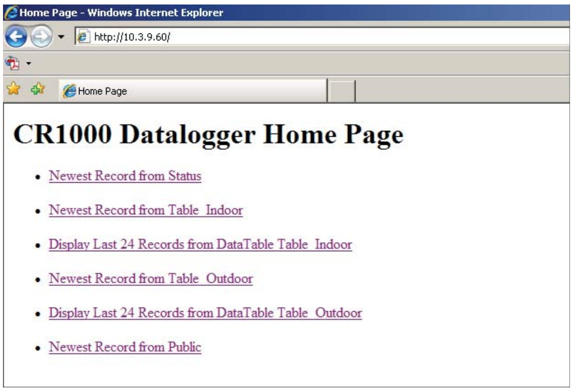


Figure 7.1: Datalogger Home Page

The CR1000 home page is built into the operating system of the logger as shown in Fig. 7.1. This page provide links to the latest outdoor and indoor records, including the status and public data to check the current settings and public variables. An example of an extract of the outdoor data table is demonstrated in Fig. 7.2.

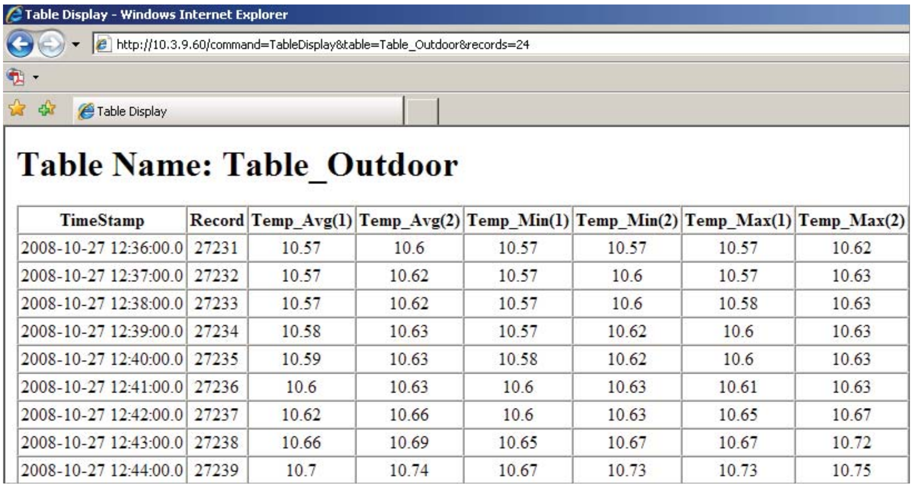


Table Name: Table_Outdoor

TimeStamp	Record	Temp_Avg(1)	Temp_Avg(2)	Temp_Min(1)	Temp_Min(2)	Temp_Max(1)	Temp_Max(2)
2008-10-27 12:36:00.0	27231	10.57	10.6	10.57	10.57	10.57	10.62
2008-10-27 12:37:00.0	27232	10.57	10.62	10.57	10.6	10.57	10.63
2008-10-27 12:38:00.0	27233	10.57	10.62	10.57	10.6	10.58	10.63
2008-10-27 12:39:00.0	27234	10.58	10.63	10.57	10.62	10.6	10.63
2008-10-27 12:40:00.0	27235	10.59	10.63	10.58	10.62	10.6	10.63
2008-10-27 12:41:00.0	27236	10.6	10.63	10.6	10.63	10.61	10.63
2008-10-27 12:42:00.0	27237	10.62	10.66	10.6	10.63	10.65	10.67
2008-10-27 12:43:00.0	27238	10.66	10.69	10.65	10.67	10.67	10.72
2008-10-27 12:44:00.0	27239	10.7	10.74	10.67	10.73	10.73	10.75

Figure 7.2: Extract of Data Table Outdoor

This table includes the latest records written to the data table outdoor including the related timestamp and record number.
Essentially the displayed data is only used for monitoring and to have a quick look at the remote site wether everything is working well. However, the HTML code can also be used to implement data for further processing within the logic control.

7.1.2 FTP Server

The CR1000 runs a FTP server. This allows the user to access the CR1000 file system via FTP with the drives being mapped into directories and folders. The root directory includes CPU and CRD (CF card). The main program is running on the CPU where the tables and calibration factors are saved to the CRD directory. Files can be pasted and copied to and from the datalogger drives as they were drives on the PC. Files can also be deleted through FTP.

The FTP server is a comfortable basis to get tables and to update calibration factors from a remote site.
Data acqusition was tested in two ways. On the one hand the FTP funtion was used to connect to the CRD directory as show in Fig. 7.3.

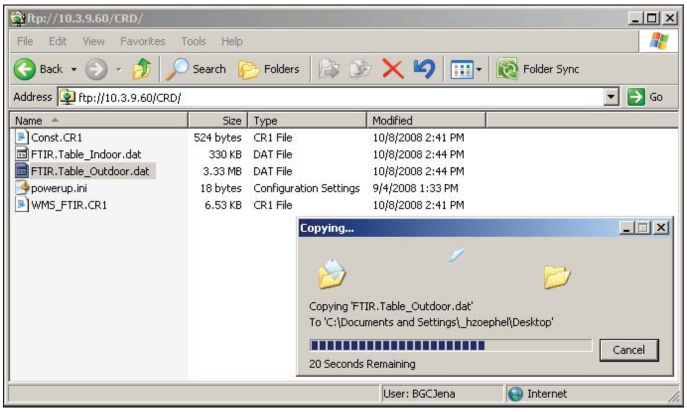


Figure 7.3: Copying Data Table Outdoor via FTP

On the other hand the transfer was tested with the use of IP-Port connection via Campbell Scientific's special software PC400 like demonstrated in Fig. 7.4.

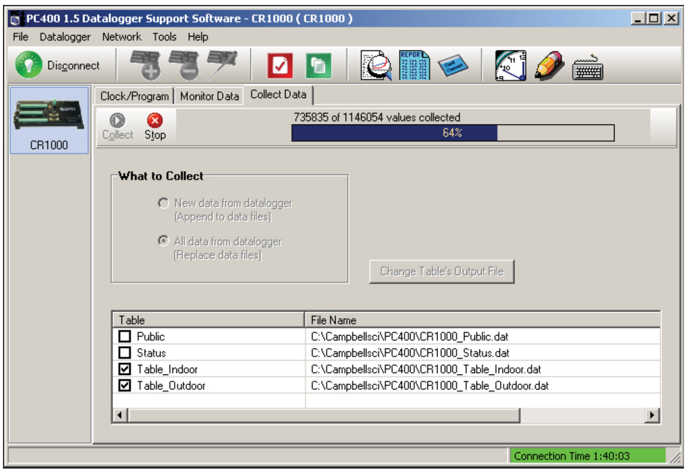


Figure 7.4: Collecting Data Tables via IP and PC400

7.1.3 Test Readings

Data were prepared for plotting some charts after file transfer has been carried out. For this purpose a selective time period at any day has been choosen.
The graphs are representing the parameters which have been determined for providing outdoor data to automatize the BGC-FTIR-System.

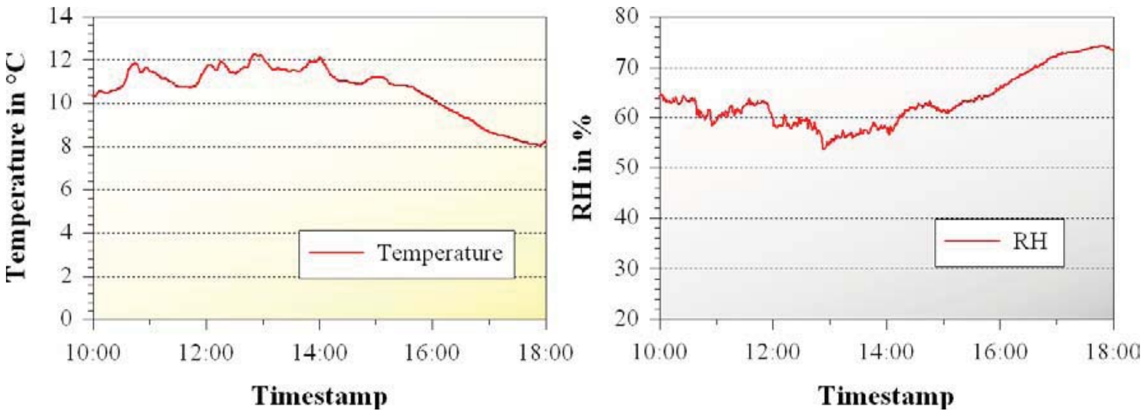


Figure 7.5: Temperature and RH

This includes temperature and humidity as well as solar radiation, wind speed and pressure as shown in Fig. 7.5, 7.6 and 7.7.
The pressure readings in Fig. 7.7 reflect the pressure inside in container due to test

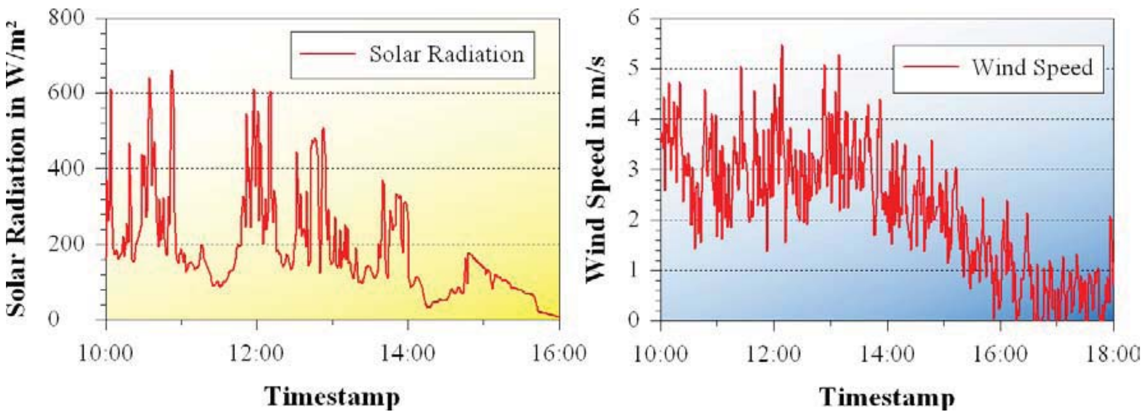


Figure 7.6: Solar Radiation and Wind Speed

purposes at that time. Precipitation is not covered within this section because it will not be detected on a quantity basis. There is only a triggered signal in case of precipitation which is processed by the programmable logic controller of the BGC-FTIR-Container.

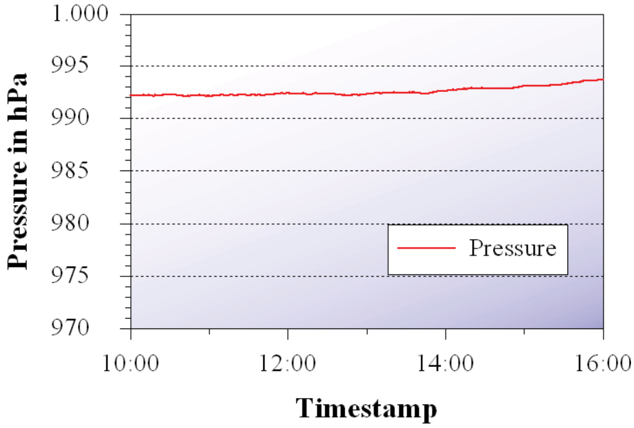


Figure 7.7: Pressure

Finally the results from inside monitoring of temperature and humidity can be found in Fig. 7.8. The graphs do demonstrate the control loop of the air conditioning. There is less need to adjust temperature and humidity in the wee hours of the morning and at night due to lower temperatures outside which is reflected by longer control loops.

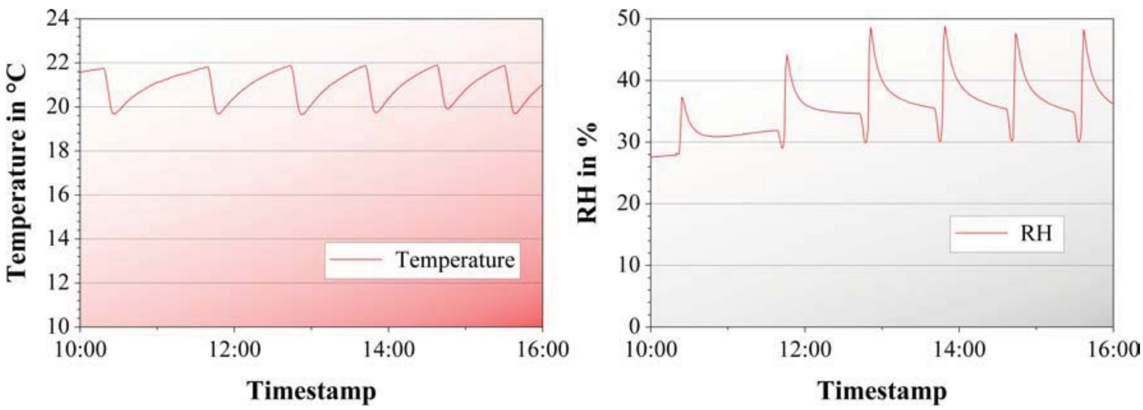


Figure 7.8: Temperature and RH

Chapter 8

Conclusion

The intention of this thesis was to establish a completely autonomous system to determine local meteorological data like temperature, humidity, wind speed, solar radiation, precipitation and pressure. Inside measurements should provide temperature and humidity readings in order to monitor the operating of the air conditioning. Thus, the system should provide a base to automatize the BGC-FTIR-Container, especially to protect the sensitive solar tracker from precipitation and other adverse environmental conditions. The system requires high reliability, high-precission pressure measurement and a easy to use data processing.

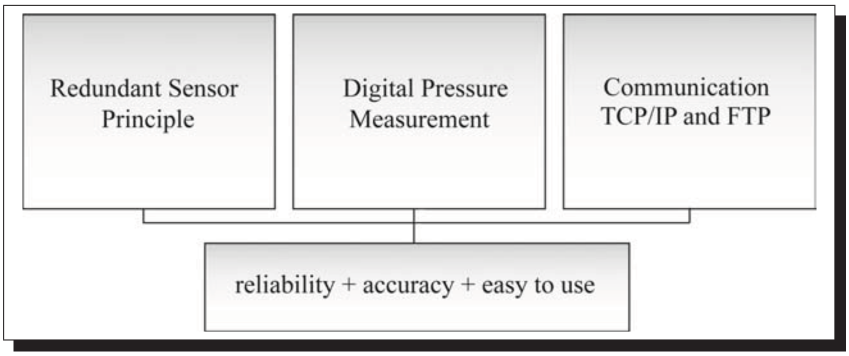


Figure 8.1: Basic Strategy

Figure 8.1 reflects the basic strategy to implement these requirements. This strategy involves the redundant sensor principle as well as the use of digital pressure measurement technology and communication via TCP/IP and FTP.

This way the system should meet the demands and should be up to standard.
The selection of the sensors aims at longevity, reliability and accuracy. The results from the test readings came up to the expectations and requirements of the system. Especially the pressure readings have shown excellent accuracy.
The data processing via TCP/IP is another fundamental component for real time data processing of the meteorological data. The use of the Ethernet/CF-Card module also enables the feature of data transfer via FTP. Therefore the user can modify the calibration factors and offsets without the need to open the main program file. Averages, minima, maxima, squared sums and number of measured data are provided to the system every minute in SI units. The pressure readings are important to calculate the mixing ratio of the measured trace gases and will be added to TCCON's database with its related solar spectra. Moreover you can draw conclusions from standard deviation by consulting the squared sum and the number of measured data. Finally the data are added to data tables with a timestamp for archival storage in order to find out possible discrepancies in solar spectra.
There are still some parameters on the operational site which have to be determined, for example at which wind speed the dome should be closed or at which time the conditions are favorable for measurements. These parameters will result from further operation and its experienced data.

After all, the weather station was built as an efficient autonomous and easy to use system. This system operates closely together with the other systems in the container and provides the required data to built up a completely automatic measurement system - the BGC FTIR-Container.

List of Figures

List of Tables

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Appendix A

CRBasic - Program Weather Station

```
'PROGRAM:
'WEATHER STATION BGC-FTIR CONTAINER
'AUTOR:
'Hendrik Zoephel (MPI-BGC, Jena, Germany)
'DATALOGGER AND PERIPHERALS:
'CR1000/NL115
'DATALOGGER SETTINGS:
'Logger IP Adress: 10.3.9.60
'Subnet Mask: 255.255.255.0
'IP Gateway: 10.9.3.1
'INSTRUMENTATION:
'temperature: 2 x T107 (Campbell)
'wind speed: 2 x 14577 (Lambrecht)
'humidity and temp.: 2 x KPC 1/6-ME (Galltec)
'humidity and temp.: 1 x CS215 (Campbell Sci.)
'global radiation: 1 x CMP3 (Kipp&Zonen)
'atmospheric press.: 2 x PTB210 (Vaisala)
'humidity/temerature: 2x CS215 (Campbell Sci.)
'CHANNEL USAGE:
'SE1,2: 2 x T107
'EX1:  2 x T107
'DIFF2: CMP3
'DIFF3,4: 2 x 14577
'DIFF5: KPC 1/6-ME (humidity)
'DIFF6: KPC 1/6-ME (humidity)
'DIFF7: KPC 1/6-ME (temperature)
'DIFF8: KPC 1/6-ME (temperature)
'COM1,2: 2 x PTB210
```

```
'C5,7: 2 x CS215
'CALCULATION:
'conversion to real units
'square sum
'PROGRAM PARAMETERS:
'Scan rate: 5 sec
'Avg. period: 60 sec.
'Min., Max. period: 60 sec.
'Square sum period:  60 sec

'____________________ DECLARATIONS_________________________________

Public TRHData(2)
Public TRHData_2(2)
Public Temp_Indoor(2) As String
Public Humid_Indoor(2) As String
Public TempString As String * 30
Public HumidString As String * 30
Public Temp_FTIR(2)
Public WindSpd_Check(2)
Public WindSpd(2)
Public WindSpd_SQ_1
Public WindSpd_SQ_2
Public N
Public Count
Public Humid(2)
Public Humid_SQ_1
Public Humid_SQ_2
Public Temp(2)
Public Temp_SQ_1
Public Temp_SQ_2
Public Pyrano(1)
Public Pyrano_SQ_1
Public OutString As String * 10
Public AirPress(2) As String * 10
Public AirPress_SQ_1
Public Airpress_SQ_2
Public AirPressString As String * 30
Public AirPressNum(2)
```

```
'________________________UNITS____________________________________

Units Temp_Indoor = deg C
Units Humid_Indoor = % RH
Units Temp_FTIR = deg C
Units WindSpd = m/s
Units WindSpd_SQ_1 = (m/s)^2
Units WindSpd_SQ_2 = (m/s)^2
Units Humid = % RH
Units Humid_SQ_1 = (% RH)^2
Units Humid_SQ_2 = (% RH)^2
Units Temp = deg C
Units Temp_SQ_1 = (deg C)^2
Units Temp_SQ_2 = (deg C)^2
Units Pyrano = W/m^2
Units Pyrano_SQ_1 = (W/m^2)^2
Units AirPress = hPa
Units AirPress_SQ_1 = (hPa)^2
Units AirPress_SQ_2 = (hPa)^2
'_______________________CONST______________________________________

Include "CRD:Const.CR1"
'____________________OUTPUT SECTION________________________________

'_______TABLE CONTAINER_______

DataTable(Table_Indoor,True,-1)

'_______CARDOUT AS RING_______

'OpenInterval
DataInterval(0,60,Sec,10)
CardOut(0,-1000)

'_______T107_______
Average(2,Temp_FTIR(1),FP2,0)
```

```
'_______CS215_______
Average(2,Temp_Indoor(1),IEEE4,False)
Average(2,Humid_Indoor(1),IEEE4,False)

'_______NUMBER OF MEASURED DATA_______
Sample(1,N,FP2)

EndTable

'_______TABLE WEATHER STATION_______

DataTable(Table_Outdoor,True,-1)

'_______CARDOUT AS RING_______
'OpenInterval
DataInterval(0,60,Sec,10)
CardOut(0,-1000)

'_______TEMP_______
Average(2,Temp(1),FP2,0)
Minimum(2,Temp(1),FP2,0,0)
Maximum(2,Temp(1),FP2,0,0)
Totalize(1,Temp_SQ_1,IEEE4,False)
Totalize(1,Temp_SQ_2,IEEE4,False)

'_______HUMID_______
Average(2,Humid(1),FP2,0)
Minimum(2,Humid(1),FP2,0,0)
Maximum(2,Humid(1),FP2,0,0)
Totalize(1,Humid_SQ_1,IEEE4,False)
Totalize(1,Humid_SQ_2,IEEE4,False)

'_______WINDSPD_______
Average(2,WindSpd(1),FP2,0)
Minimum(2,WindSpd(1),FP2,0,0)
Maximum(2,WindSpd(1),FP2,0,0)
Totalize(1,WindSpd_SQ_1,IEEE4,False)
Totalize(1,WindSpd_SQ_2,IEEE4,False)
'Sample(1,Check1,Boolean)
'Sample(1,Check2,Boolean)
```

```
'_______AIRPRESS_______
Average(2,AirPress(1),IEEE4,0)
Minimum(2,AirPress(1),IEEE4,0,0)
Maximum(2,AirPress(1),IEEE4,0,0)
Totalize(1,AirPress_SQ_1,IEEE4,False)
Totalize(1,AirPress_SQ_2,IEEE4,False)

'_______PRYRANO_______
Average(1,Pyrano,FP2,0)
Minimum(1,Pyrano,FP2,0,0)
Maximum(1,Pyrano,FP2,0,0)
Totalize(1,Pyrano_SQ_1,IEEE4,False)

'_______NUMBER OF MEASURED DATA_______
Sample(1,N,FP2)

EndTable

'________________________PROGRAMM__________________________________

BeginProg

'_______SET COMMUNICATION-PARAMETERS FOR PTB210_______
SerialOpen(Com1,9600,10,0,0)
SerialOpen(Com2,9600,10,0,0)

Scan(5,Sec,0,0)

'_______SEND STRING ".P<cr><lf>" TO PTB210_______
SerialOut(Com1,Command,"",0,100)
SerialOut(Com2,Command,"",0,100)

'_______RECEIVE SERIAL DATA AS STRING FROM PTB210_______
SerialIn(AirPress(1),Com1,100,10,10)
SerialIn(AirPress(2),Com2,100,10,10)

'_______CONVERTING STRING INTO NUMERIC VALUE_______
AirPressString = AirPress(1) + "," + AirPress(2)
SplitStr(AirPressNum(1),AirPressString,",",2,0)
AirPress_SQ_1 = AirPressNum(1) * AirPressNum(1)
AirPress_SQ_2 = AirPressNum(2) * AirPressNum(2)
```

```
'_______RECEIVE VALUES, VOLTAGES ARE CONVERTED IN REAL UNITS________
SDI12Recorder(TRHData(),5,"0","R!",1,0)
SDI12Recorder(TRHData_2(),7,"0","R!",1,0)

'_______ALLOCATION OF INDOOR MEASUREMENTS TO STRINGS_______
TempString = TRHData(1) + "," + TRHData_2(1)
HumidString = TRHData(2) + "," + TRHData_2(2)
SplitStr(Temp_Indoor(1),TempString,",",2,0)
SplitStr(Humid_Indoor(1),HumidString,",",2,0)
Therm107(Temp_FTIR(1),2,1,Vx1,0,_50Hz,1,0)
VoltDiff(WindSpd(1),2,mV2500,3,True,0,_50Hz,wind_multiplier,wind_offset)
WindSpd_SQ_1 = WindSpd(1) * WindSpd(1)
WindSpd_SQ_2 = WindSpd(2) * WindSpd(2)
VoltDiff(Humid(1),2,mV2500,5,True,0,_50Hz,humid_multiplier,humid_offset)
Humid_SQ_1 = Humid(1) * Humid(1)
Humid_SQ_2 = Humid(2) * Humid(2)
VoltDiff(Temp(1),2,mV2500,7,True,0,_50Hz,temp_multiplier,temp_offset)
Temp_SQ_1 = Temp(1) * Temp(1)
Temp_SQ_2 = Temp(2) * Temp(2)
VoltDiff(Pyrano(1),1,mV2_5,2,True,0,_50Hz,pyrano_multiplier,pyrano_offset)
Pyrano_SQ_1 = Pyrano * Pyrano

'_______COUNTER OF MEASURED DATA PER INTERVAL_______
Count = Count + 1
N = Count
If TimeIntoInterval(0,60,sec) Then
Count = 0
EndIf

'_______PUT OVER DATA TO TABLE_______
CallTable(Table_Outdoor)
CallTable(Table_Indoor)

NextScan

EndProg
```

Appendix B

CRBasic - Input file CONST.CR1

```
'-----------------------

'COMMAND FOR PTB210
'-----------------------
Const = CR = CHR(13) 'carriage return
Const = LF = CHR(10) 'line feed
Const = Command = ".P" + CR + LF

'-----------------------

'MULTIPLIER AND OFFSETS
'-----------------------
Const = wind_multiplier = 0.03125
Const = wind_offset = -12.5
Const = humid_multiplier = 0.1
Const = humid_offset = 0
Const = temp_multiplier = 0.1
Const = temp_offset = -30
Const = pyrano_multiplier = 75.1314800901577
Const = pyrano_offset = 0
```

BGC FTIR-CONTAINER
INSTRUCTION MANUAL

WEATHER STATION

Issued: August 2008

Max Planck Institute for Biogeochemistry

Jena, January 9, 2009

Contents

1.1 Introduction

Measurements with the MPI-BGC FTIR system are only possible when the sun is visible. However, the solar tracker which guides the sunlight into the instrument has to be protected from precipitation and other adverse environmental conditions. Therefore the FTIR system needs a weather station to determine if the local weather conditions are favourable for measurements or if the solar tracker should be protected.

Figure 1.1: The BGC-FTIR weather station

The main parameters which will be determined are temperature, humidity, solar radiation, wind speed and precipitation. To increase the reliability of the system, all of the crucial parameters are measured redundantly with duplicate sensors or sensors of different principle. The redundant sensor principle is also useful to correct for long-term drift of the sensors.

Temperature and humidity are measured with two compact meteorological sensors. Wind speed is provided by two cup anemometers with high reliability. Precipitation is detected by a light barrier and a contact conclusion system. A pyranometer provides measurements of the global solar radiation. The high precision pressure measurement is implemented with a digital sensor which provides maximum accuracy as well as long-term stability. A thermistor and a digital temperature/humidity sensor are used for monitoring the conditions inside the BGC-FTIR-Container.

The sensor signals are collected by the Datalogger CR1000 at several analog and digital inputs. The CR1000 and the sensors form a completely autonomous system. Communication with the master PC is accomplished over an ethernet connection with the Ethernet/Compact Flash Module NL115. Data are stored in tables on the CPU as well as on the CF-Card.

1.2 The Sensors

1.2.1 Temperature/Humidity Galltec/Mela KPC 1/6-ME

User Information

The sensor is placed outdoors and therefore used in a weather gurad (ZA 161/1-type) to avoid direct sunlight as well as other adverse effects. The sensor can be installed in any postiton. However, do not place it in a position where water ingrees can occur. Dew formation and splashes do not damage the sensor, although corrupt measurement readings are recorded until all the moisture on and directly around the sensor element has dried up.

Figure 1.2: KPC 1/6-ME and Weather Guard

Because measurement conditions can be at high wind speeds or the sensor can be exposed to salt mist and sandIt the version with the sintered high-grade steel filter is used (ZE 21 response time $<$ 1,5 minutes).
Therefore the dynamic behaviour changes. To avoid corrosion it is recommended to apply some acid-free grease on the screw thread sparingly.

Maintenance

The protective filter should only be screwed off carefully to check functioning with a humidity standard. Take care not to touch the highly sensitive sensor element. If necerssary, the soiled sintered filter can be screwed off and rinsed. When you screw them back on, bear in mind that the sensor will not meassure accurately again until everything is completely dry. For ballancing the offset after calibration see section 1.3.3 on page 39.

Mounting

The weather guard can easily be mounted on the mast on top of the BGC-FTIR-Container. It has to be pointed out that there is a difference in height because of the construction of the clamps.

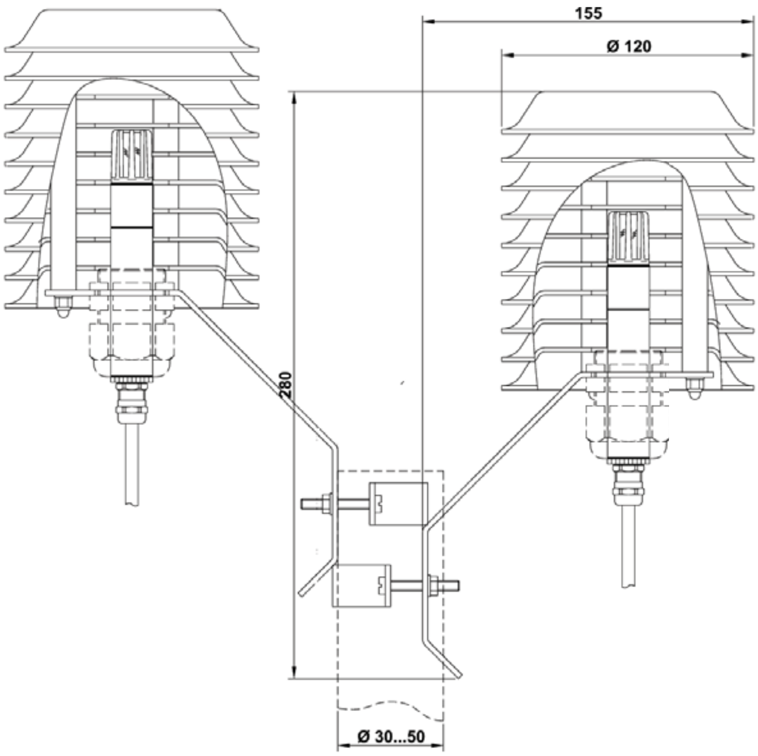

Figure 1.3: Mounting of the Weather Guard and the Sensor

NOTE: **Take care not to damage the sensing elemet when screwing-off the filter.**

Connection

The connection cable is led along the mast and has to be fastened using appropriate cable ties. To sensor must be properly grounded. Make sure that the cable is protected from humidity on both sides.

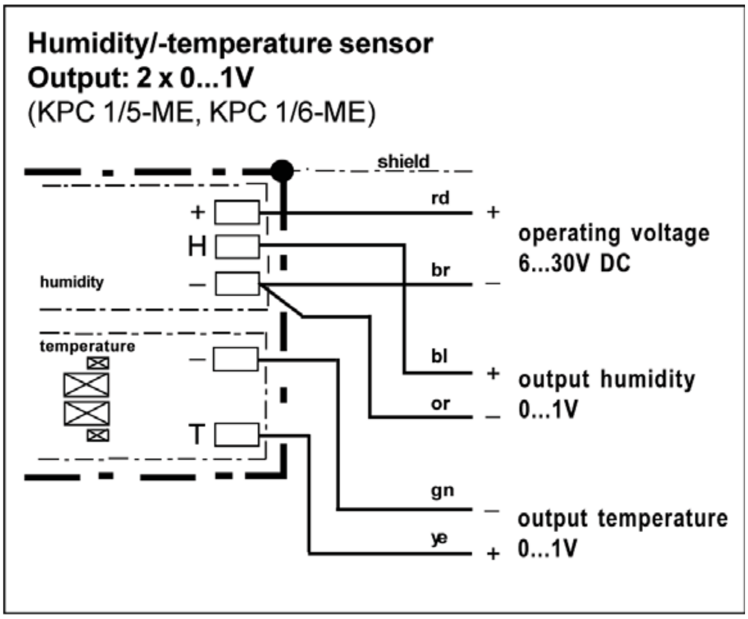

Figure 1.4: Connection Diagram

For connecting the sensor simply follow Fig. 1.4. See section 1.4.1 on page 42 for more details.

1.2.2 Wind Speed Lambrecht 14577

User Information

When weather condition are are at high wind speeds, the dome of the solar tracker should close for protecting the sensitive instrument. Thus, wind speed is one of the parameters which are detemined for protecting the solar tracker. To increase the reliability of the system, wind speed is provided by two cup anemometers.

Figure 1.5: Lambrecht Wind Speed 14577

The sensors main advantages are the electromagnetic, non-impact measuring principle for precise data acquisition and the double supported ball bearing of the rotation axis. These characteristics assure high reliability, longevity, lower friction as well as lower abrasion. Fhurthermore there is an automatic heating element to avoid freezing of the ball bearing.

Maintenance

The Sensor design permits long periods of maintenance-free operation. A regular visual verification of the sensor as well as a sensor calibration is recommended every two years. In this case remove the cable-plug connection and the lower nut from the sensors and take it out of the traverse for further services.

Mounting

There are bores with a diameter of 30 mm at each end of the mast's traverse First remove the lower nut and put the sensor with assembled cable sidewise into the bore. Attach the sensor with the flat side of deteached nut from below and tighten with a suitable tool until the sensor is attached firmly.

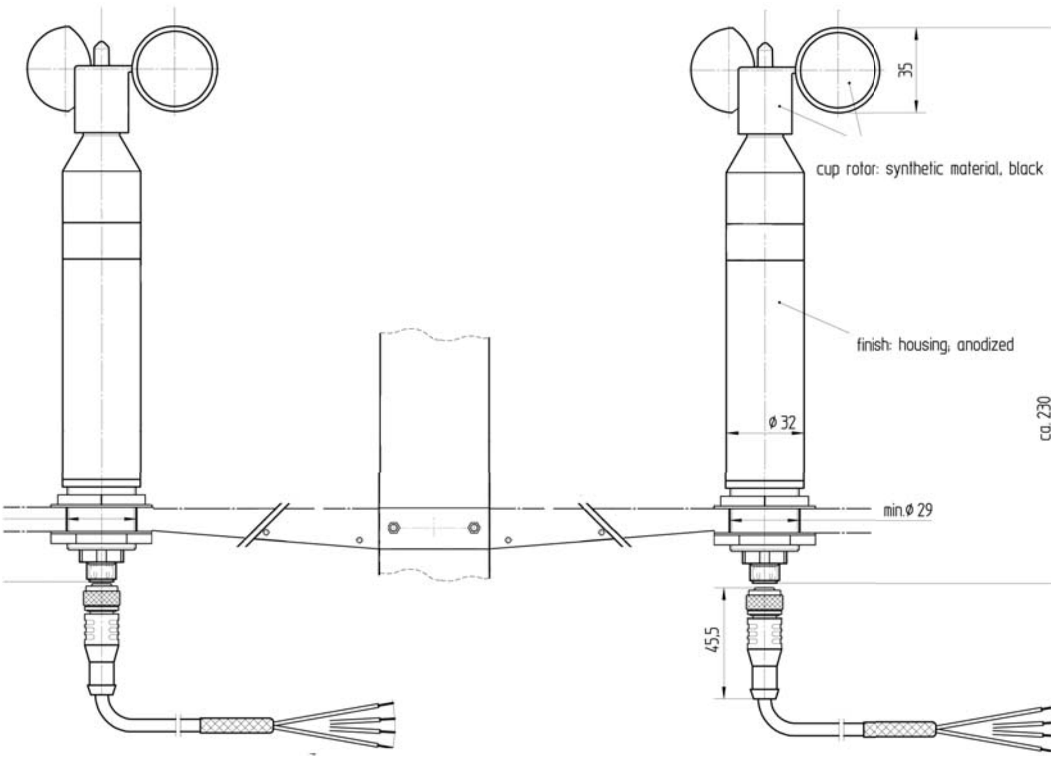

Figure 1.6: Mounting of Lambrecht 14577

Make sure, that the place of installation is not under the lee of great obsacles. If there are any obstacles, pay heed that the distance between the obstacles and the sensor should be 10 times the height of the obstacles.
This way you can assure that the installation corresponds to the definition of an undisturbed terrain.

Connection

The connection cable is led along the mast and has to be fastened using appropriate cable ties. To reduce the risk of inductive interference the sensor must be properly grounded. Make sure, that the cable is protected from humidity on both sides and that the cable plug connection is properly fixed.

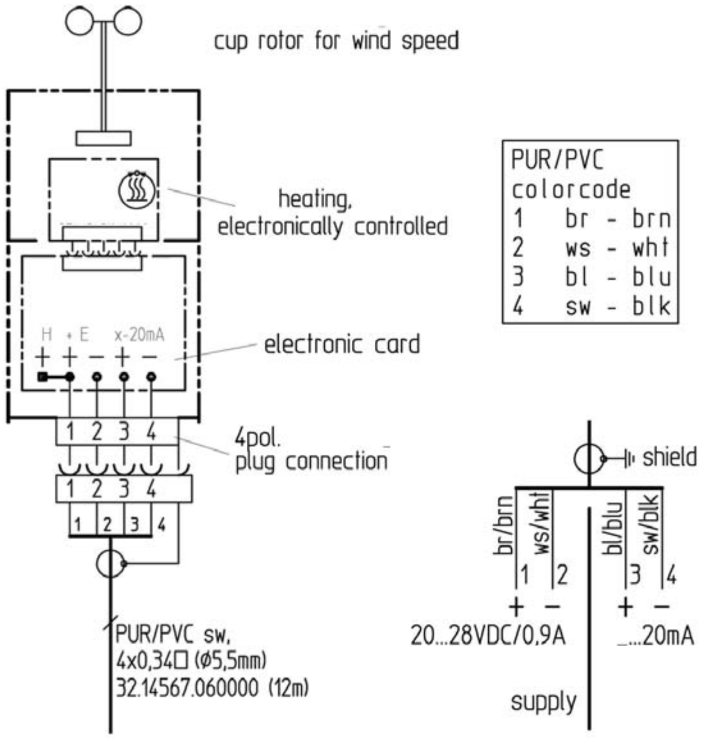

Figure 1.7: Connection Diagram

For connecting the sensor simply follow Fig. 1.7. See section 1.4.1 on page 42 for more details.

1.2.3 Precipitaion Lambrecht 15153

User Information

The precipitation detector transmits signals to determine the beginning and the end of precipitation and the duration of the period of precipitation.

Figure 1.8: Lambrecht Precipitation Sensor 15153

In the automatic weather station of the BGC-FTIR-Container this sensor is used to report status and to transmit a control signal to the SPS. This is to protect the solar tracker by closing the dome to avoid wetting of the sensitive instrument. Precipitation in the form of drizzle, rain, snow or hail is detected by means of an IR light barrier system and trigger a signal within the connected electronics. A built-in incidence-filter smoothes the triggering of swiching signals in case of individual incidences, as for example leafs, bird droppings, insects etc. For this, a certain number of at least n incidences should have occured within a time-frame of 50 sec. The number of drop incidences (1...15) can be selected through the DIP switch 2 on the circuit board. For details see section 1.2.3 on page 16. When precipitation ends, the switching signal is reset after a selectable switch-off delay. The sensor is equipped with a heating (temperature > 0 °C) system for extreme weather conditions. This avoids ice and snow forming on the housing's surface.

Maintenance

Dust and dirt may accumulate and form a layer on the sensing element. This, however, is usually washed off by precipitation. The windows of the sensor should be checked and cleaned on every maintenance visit.

Mounting

The mounting system of the instrument is designed for attachment to a mast. When mounting, make sure that the precipitation can easily reach the opening of the sensor and that the instrument is not exposed to strong vibrations or shocks.

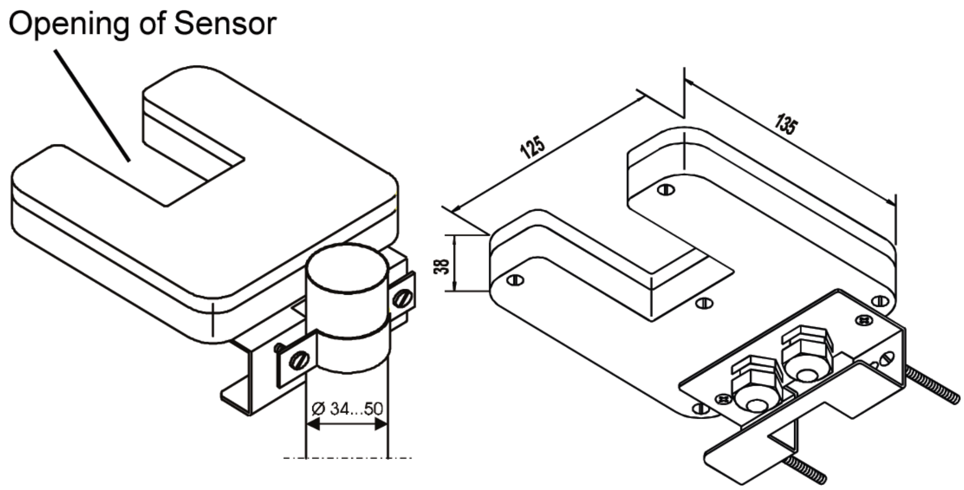

Figure 1.9: Mounting of Lambrecht 15153

Adjusting of Incidences and Swich-off Delay

To select the number of incidences and switch-off delay remove the cover with its 5 screws with a screwdriver. Now the DIP swiches in Fig. 1.10 are accessible.

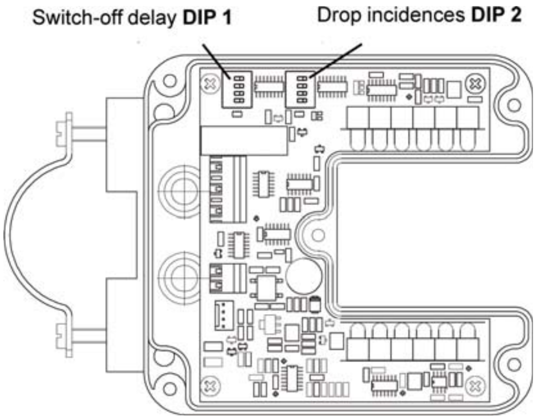

Figure 1.10: Circuit board with DIP switches

The adjustment carried out for protecting the solar tracker is set to 3 drop incidences within 50 sec. with a swich-off delay of 25 sec. If this adjustment is to be changed, the **swich-off delay** is set through the **DIP switch 1** and the number of **drop incidences** is selected through the **DIP switch 2** according to Table 1.1.

S1	S2	S3	S4	time[s]	S1	S2	S3	S4	drops
1	0	0	0	25	1	0	0	0	1
0	1	0	0	50	0	1	0	0	2
1	1	0	0	75	1	1	0	0	3
0	0	1	0	100	0	0	1	0	4
1	0	1	0	125	1	0	1	0	5
0	1	1	0	150	0	1	1	0	6
1	1	1	0	175	1	1	1	0	7
0	0	0	1	200	0	0	0	1	8
1	0	0	1	225	1	0	0	1	9
0	1	0	1	250	0	1	0	1	10
1	1	0	1	275	1	1	0	1	11
0	0	1	1	300	0	0	1	1	12
1	0	1	1	325	1	0	1	1	13
0	1	1	1	350	0	1	1	1	14
1	1	1	1	375	1	1	1	1	15
Switch-off delay DIP 1					Drop incidences DIP 2				

Table 1.1: Table for Adjusting Incidences and Swich-off Delay

After setting up the sensor screw the case back on and power up the supply voltage. The setting of the relay output shows "no precipitation".

<u>**NOTE:**</u> **Make sure that you allways disconnect the supply voltage for set up the sensor!**

Connection

The connection cable is led along the mast and has to be fastened using appropriate cable ties. The sensor must be properly grounded. Make sure, that the cable is protected from humidity on both sides.

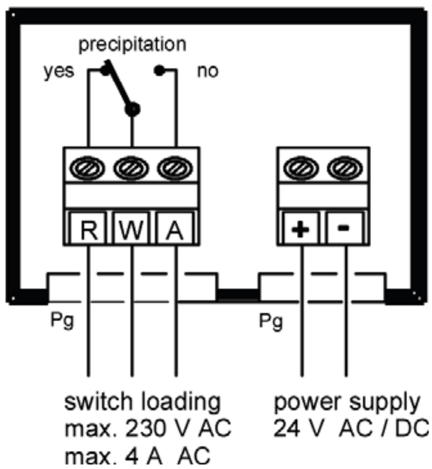

Figure 1.11: Connection Diagram

To access the connection terminal, remove the 5 screws of the cover with a slotted screwdriver. The electrical connection is carried out according to Fig. 1.11. For more details see section 1.4.1 on page 42.

<u>**NOTE:**</u> **The relay output is connected in a manner that a failure of supply voltage is signaled as "precipitation"!**

1.2.4 Precipitaion Lambrecht 15152

User Information

In order to provide a detection of all kinds of precipitation the precipitation instrumentation is enlarged by the Lambrecht 15152. At the beginning of a precipitation event rain drops will cause a conductive connection between the two sensing electrodes to trigger the relay contacts. By this means a relay is cut through and the controlling event is done.

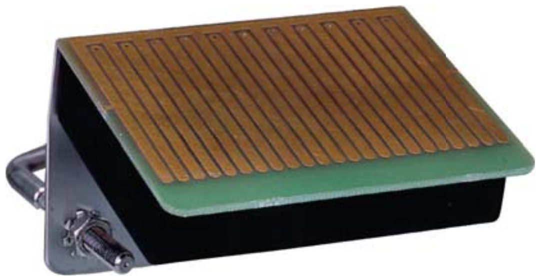

Figure 1.12: Lambrecht Precipitation Sensor 15152

The sensor surface is heated in two levels. The first level is switched on constantly to prevent ice and dew formation. As soon as the sensing area is moistured, the second heating level is switched on to make sure that the surface drys up as soon as possible. After drying up, the second level is switched off again.

Maintenance

According to the atmospheric pollution a layer of dirt can form on the sensors surface. This dirt has an isolating effect and may lead to short-circuits. So the sensor is not able to set off an accurate signal by falling rain. Therefore the sensor surface has to be cleaned with a light cleaner on every maintenance visit.

NOTE: **Take care not to damage the sensing electrodes by using the wrong cleaner!**

Mounting

The Sensor can be fixed at the mast on the top of the BGC-FTIR-Container. When selecting the installation place please pay attention that the sensing surface points in direction to the sky. Also check that the installation site is free of obstacles to the close surrounding. Maintaine a distance of 10 times the hight of the obstacles to assure that the installation corresponds to the definition of an undisturbed terrain.

Connection

The connection cable is led along the mast and has to be fastened using appropriate cable ties.

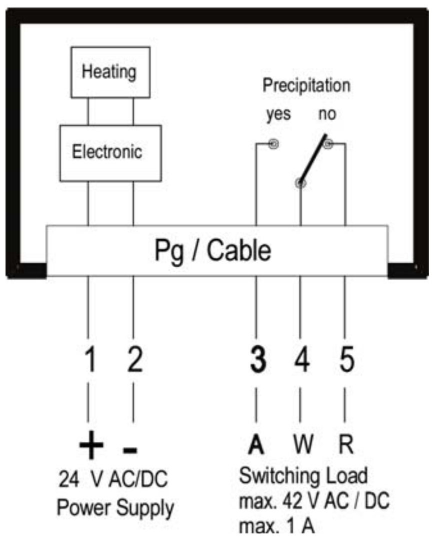

Figure 1.13: Connection Diagram

The electrical connection is carried out according to Fig. 1.13. For more details see section 1.4.1 on page 42.

NOTE: **After connecting the sensor to the power supply the relay will stay in the precipitation = yes state for about 5.5 minutes. After that, the sensor will resume normal operation.**

1.2.5 Solar Radiation Kipp & Zonen CMP3

User Information

Measurements with the BGC-FTIR-System are only possible when the sun is visible. Therefor the Pyranometer CMP 3 comes into operation. The thermopile sensor construction measures the solar energy that is received from the total solar spectrum and the whole hemisphere (180 degrees field of view). The output is expressed in W/m^2 according to equation (1.1).

$$E_{solar} = \frac{U_{emf}}{S} \tag{1.1}$$

- E_{solar} = Irradiance [W/m^2]
- U_{emf} = Output Voltage [V]
- S = Sensitivity [V/(W/m^2)]

Figure 1.14: Kipp & Zonen CMP3

The CMP 3 is intended for shortwave global solar radiation measurements (spectral range 310 to 2800 nm) and measures irradiance up to 2000 W/m^2 with a response time $<$ 18 seconds.

Maintenance

Dust and dirt may collect on the glass dome. This, however, is usually washed off by the precipitation, but can disturbe the measurements if not. The glass dome of the sensor should be checked and cleaned with water or alcohol on every maintenance day. Also check the level of the sensor and adjust with its set screws if required. The sensor should be recalibrated every two years.

Mounting

The sensor is designed for attachement to a mast. A mounting sleeve is installed at the top of the mast on th BGC-FTIR-Container where you can fix the pyranometer with 2 screws and a screwdriver according to Fig. 1.15.

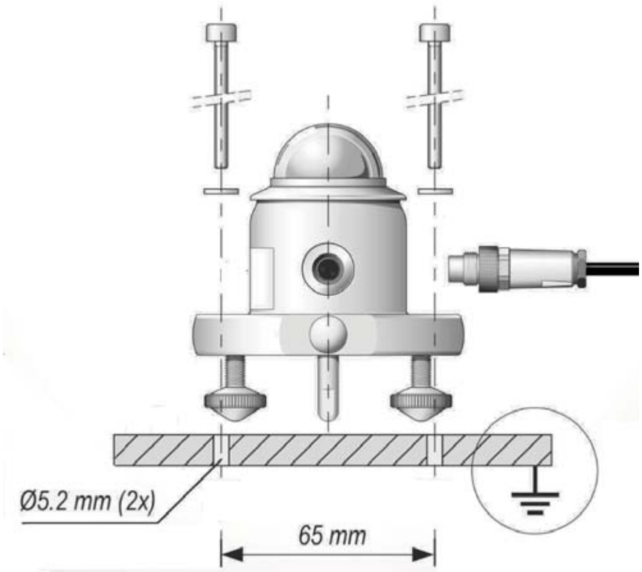

Figure 1.15: Mounting of Kipp & Zonen CMP3

First remove the white sun shield by clipping it off to access the bores and the spirit level at the base of the pyranometer. Tighten the sensor with two screws to the mounting sleeve on the top of the mast and use the adjustment screws for leveling the sensor. Afterwards snap-on the white sun shield again and reconnect the cable.

Make sure that the place of installation is not shadowed by great obstacles. If there are any obstacles, make sure that the distance between the obstacles and the sensor is at least ten times the height of the obstacles.
This way you can assure that the installation corresponds to the definition of an undisturbed terrain.

<u>NOTE:</u> **Do not forget to level the sensor after fixing it on the mounting sleeve.**

Connection

The connection cable is led along the mast and has to be fastened using appropriate cable ties. The sensor must be properly grounded. Make sure that the cable plug connection is properly fixed.

Pyranometer - Connection		
Wire	Function	Connect with
Red	+	+ (Hi)
Blue	-	- (Lo)
Shield	Housing	Ground

Table 1.2: Connection diagram

For connecting the sensor simply follow Table 1.2. See section 1.4.6 on page 45 for more details.

1.2.6 Pressure Vaisala PTB210

User Information

The pressure measurement requires high accuracy and precision to calculate volume mixing ratio of the measured trace gases. So the automatic weather station is equipped with two digital Vaisala PTB 210 which feature digital output in a range of 500 to 1100hPa. A third sensor of the same type is used for the leap-frog recalibration scheme (for details see figure 1.17). They operate in a wide temperature range and the rugged corrosion-resistant housing provides an IP65 standardized protection against sprayed water.

Figure 1.16: Vaisala PTB 210

Maintenance

The barometers are digitally adjusted and calibrated by using electronic working standards. To maintain the reliability of the system the leap-frog recalibration scheme is carried out according to Fig. 1.17.

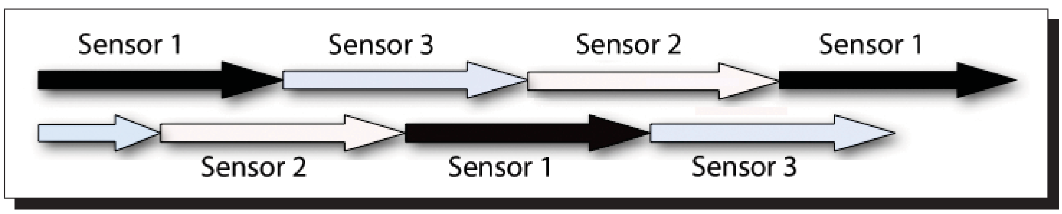

Figure 1.17: Leap-Frog recalibration scheme

Two barometers are always used for operational measurements. Upon every maintenance visit, one of the barometers should be replaced with the recalibrated spare barometer. See this section on page 24 for details.

Mounting

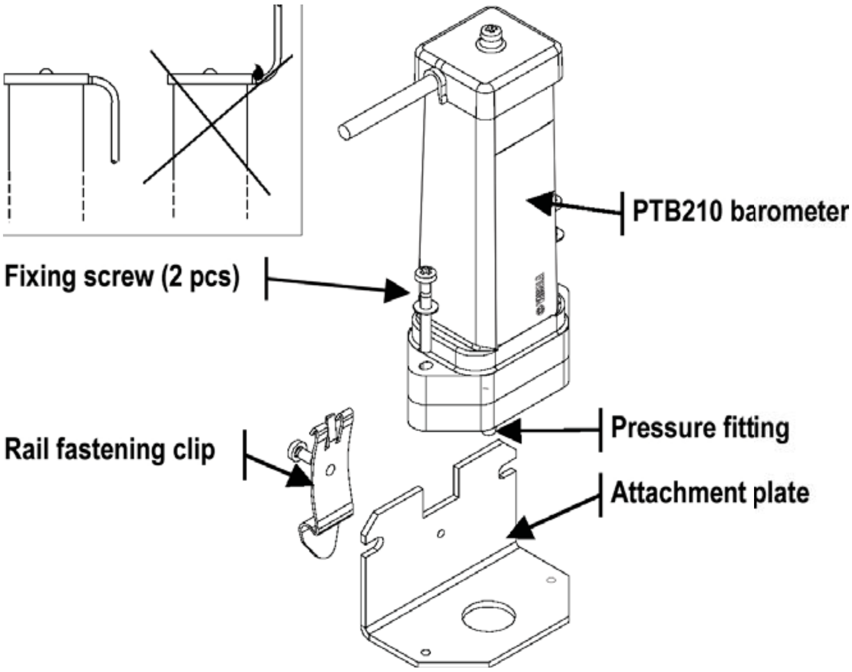

Figure 1.18: Mounting of Vaisala PTB 210

NOTE: **Always place the barometer in a way that the pressure fitting is downwards and check that the cable is not taken upwards from the barometer. This is to prevent water flowing along the cable, and gathering close to the feed-through.**

Operation

The PTB210 can be operated through a serial line with any terminal emulator program and the commands given in the following pages. Note to use the right parameters for communication with the RS232-Port on your PC or laptop.
(baud rate 9600, parity even, data bits 7, stop bits 1)

General and Communication

The **general command format** is:

.ZZZ.xxx<cr>

- ZZZ = event
- xxx = given value of a parameter

If there are several barometers on same line, it is necessary to use an **ID-code**:

123.ZZZ.xxx<cr>

The default ID-code is 0. If necessary, you can **change the ID**:

.ID.xxx<cr>

- xxx = identification code (max. 15 characters)

To set the **baud rate** of the barometer use the command:

.BAUD.xxxx<cr>

- xxxx = baud rate (1200...19200

<u>**NOTE:**</u> **The barometer does not echo the given commands nor confirm the new settings by echoing them. However, the settings can be checked with the command ?<cr>. Make sure to reset the barometer with the command .RESET<cr> to activate the new settings.**

Setting of Measurement Parameters

Before using the barometer you have to set up the parameters. The following commands will give you an overview in terms of possible measurement settings. To check the actual settings use **?<cr>**.

To set the **number of measurements** performed in one minute use the command:

.MPM.xxxx<cr>

- xxxx = number of measurements per minute (6...4200)

To set the number of measurement points that are used for calculating an **average pressure reading** use the command:

.AVRG.xxx<cr>

- xxxx = number of measurements (not a moving number) of which the average is calculated (0...255)

__NOTE:__ **Make sure to reset the barometer with the command .RESET<cr> to activate the new settings. The settings can be checked with the command ?<cr>.**

Operating Commands

To **output one single pressure reading** with two decimals (as used in the programming of the weather station) use the command:

.P<cr>

For **continous output** of the pressure readings use the command:

.BP<cr>

The output depends on the measurement rate and the averaging setting (see this section on page 26). Output is stopped by pressing the enter-key (<cr>). To **select a pressure unit** use the command:

.UNIT.x<cr>

X	UNIT	X	UNIT
0	hPa (default)	6	kPa
1	mbar	7	Pa
2	inHg	8	mmH_2O
3	psia	9	inH_2O
4	torr	10	bar
5	mmHg		

For **output with the unit** use the command:

.FORM.1<cr>

For **output without the unit** use the command:

.FORM.0<cr>

NOTE: **Make sure to reset the barometer with the command .RESET<cr> to activate the new settings. The settings can be checked with the command ?<cr>.**

Power Down and Saving of Calibration Date

If you want to set the instrument to **power down state** use the command:

.PD<cr>

The barometer does not measure the pressure in this state. It is re-activated by pressing the enter-key or by sending a <cr> over the serial line. After this, the barometer settles in about half a second. Afterwards any command can be given to the barometer.

To **store the last calibration date** use the command:

.CALD.xxx<cr>

- xxx = calibration date (max. 15 characters)

Basic Informations about the Barometer Settings

In Order to get the **status of settings** use the command:

?<cr>

As result you should receive something like shown in Fig. 1.19.

```
.?<cr>
PTB210 Ver 1.0
CAL DATE          :1999-06-10
ID CODE           :10
SERIAL NUMBER     :T00100004
MULTIPOINT CORR:ON
MEAS PER MINUTE:     60
AVERAGING         :    0
PRESSURE UNIT     : hPa
Pressure Min...Max:    500   1100
LOW CURRENT MODE
RS485 RESISTOR OFF
```

Figure 1.19: Vaisala PTB 210 status

NOTE: **Make sure to reset the barometer with the command .RESET<cr> to activate the new settings. The settings can be checked with the command ?<cr>.**

Connection

For connecting the sensor simply follow Table 1.3. See section 1.4.6 on page 45 for more details.

PTB 210 - Connection	
Wire	Signal
Greey	RX
Green	TX
Blue	Ground
Pink	Power (12V)
Brown	- Not Connected -
White	- Not Connected -
Yellow	External power control

Table 1.3: Connection Diagram

1.2.7 Temperature Probe Campbell Scientific T107

User Information

A low pressure gas cell filled with HCL is used to provide narrow absorption lines at a number of different frequencies across the bandwidth of the FTIR instrument. The gas cell acts as an internal calibration reference and is placed directly into the solar beam. Campbell Scientific‘s Temperature Probe T107 is used for monitoring the temperature inside the FTIR spectrometer next to the gas cell because absorption lines depend on temperature. Two redundant sensors are used for monitor the temperature of the gas cell.

Figure 1.20: Campbell Scientific Temperature Probe T107

AC power lines can be the source of electrical noise. Because the CR1000 is in an electronically noisy environment, the T107 is measured with 50 Hz rejection.

Maintenance

The T107 is a very user-friendly sensor which requires minimal maintenance. For most applications it is unnecessary to recalibrate the thermistor offset. However, you can determine the offset by placing the sensor in the calibration chamber at a certain value of e.g. 0 °C. The offset has to be placed in the **Const.CR1** file on the CF Card of the CR1000. For details see section 1.3.3 on page 39.

Mounting

The sensor is placed next to the gas cell in the FTIR instrument.

Connection

The connection is carried out to the table in section 1.4.6 on page 45. Pay attention that the cable is properly fixed.

T107 - Connection	
Wire	Signal
Red	Signal
Black	Excitation
White	Signal Ground
Clear	Shield

Table 1.4: Connection Diagram

1.2.8 Temperature/Humidity Campbell Scientific CS215

User Information

To monitor the conditions inside the BGC-FTIR-Container a digital Temperature/Humidity Sensor CS215 comes into operation. It features a digital SDI-12 output allowing simple connection to the Control-Port of the Datalogger CR1000.

Figure 1.21: Campbell Scientific CS215

Maintenance

Because the sensor is used inside only minimal maintenance is required. However, if there should appear dirt on the filter, simply clean with water or replace it. The life of the chip element is quoted as many years with a typical drift of less than 1% per year. If there is a need to change the sensing element please see the operating manual.

Mounting

The sensor is mounted at an appropriate place inside the BGC-FTIR-Container.

<u>NOTE:</u> **Take care not to damage the sensing element when screwing-off the filter.**

Connection

The connection is carried out according to the table in section 1.4.6 on page 45. Make sure that the cable is properly fixed.

CS215 - Connection	
Wire	Signal
Red	12 V Power Suply
White	Ground
Black	Ground
Green	Signal
Clear	Shield

Table 1.5: Connection Diagram

1.3 Data Acquisition - Datalogger CR1000

The CR1000 must be grounded to minimize the risk of damage by voltage transients associated with power surges and lightning induced transients. Earth grounding is required to form a complete circuit for voltage clamping devices internal to the CR1000.

1.3.1 Connecting Panel

The following notes give an outline of the ports which are used for operating the instrumentation of the automatic weather station.
Figure 1.22 gives an overview of several possibilities to connect sensors and peripheral devices to the Datalogger CR1000.

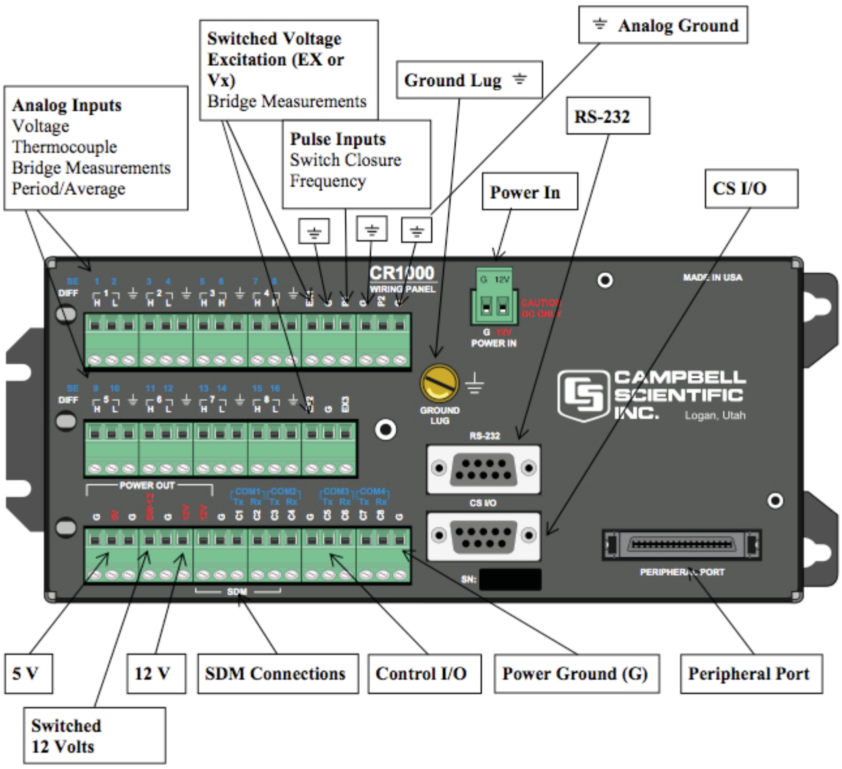

Figure 1.22: Campbell Scientific CR1000

Analog and Switched Voltage

The Temperature/Humidity Sensor KPC 1/6 ME and the Pyranometer CMP3 transmit analog voltage which is measured at the DIFF-Ports of the Datalogger CR1000.

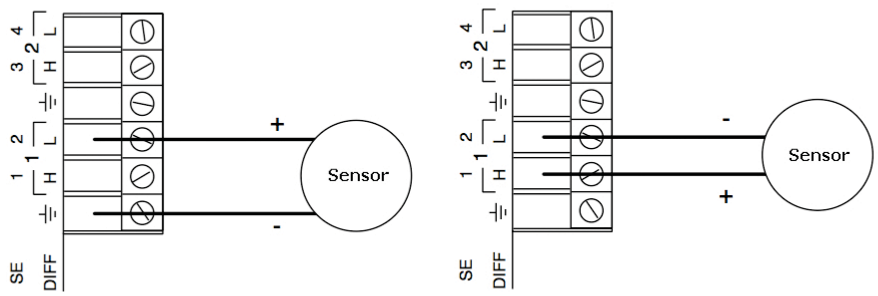

Figure 1.23: Connecting to SE- and DIFF-Ports

Lambrechts Wind Speed 14557 transmits analog current. Anyway, this signal is also measured at the DIFF-Port of the Datalogger CR1000 but has to be transformed into analog voltage by using a high-precision shunt resistor of 100 Ohm. The Temperature Probe T107 has to be excited by the EX-Port because of switched voltage and is measured at the SE-Port. For details see section 1.3.3 on page 42 and 45.

Serial Data

The digital pressure sensor PTB210 transmits serial data which are received at the COM-Port of the Datalogger CR1000. For connection see section 1.4.6 on page 45 . For setting up like shown in section 1.2.6 on page 25 simply connect to the RS232-Interface on your PC or Laptop according to figure 1.24 and start communication with a terminal program.

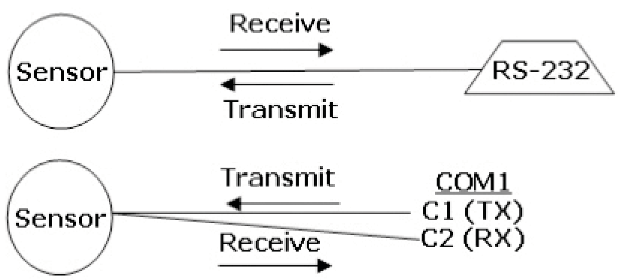

Figure 1.24: Connecting to COM-Ports and RS232

NOTE: **Take care to use the right parameters for communication through the serial line. (section 1.2.6 on page 25)**

SDI-12

Campbell Scientifics Temperature/Humidity Sensor CS215 features a digital SDI-12 output. It allows simple connection to the Control-Port of the Datalogger CR1000 according to figure 1.25. Only the TX-Ports can be used to receiving a SDI-12 output. For details connecting the CS215 see section 1.4.6 on page 45.

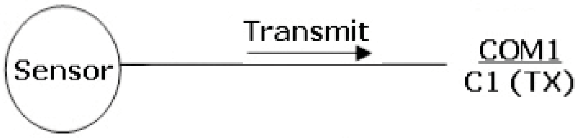

Figure 1.25: Connecting to Control-Ports

CS I/O

This port of the Datalogger CR1000 is used to connect the keyboard display CR1000KD. For details see section 1.3.2.

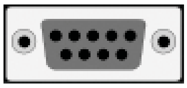

Figure 1.26: CS I/O Port

Peripheral Port

To have the alternative to save data to a CF-Card and to operate through a ethernet line (access to filesystem via ftp) the Datalogger CR1000 is equipped with the Ethernet/CompactFlash Module NL115. It is connected to the 40-pin peripheral port on the CR1000. For details see section 1.3.2.

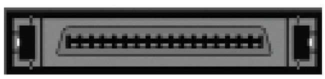

Figure 1.27: Peripheral Port

1.3.2 Peripheral Devices

Keybord Display - CR1000KD

The CR1000 has an optional keyboard display, the CR1000KD. The table below shows a few keys with its special functions.

Figure 1.28: Keyboard Display CR1000KD

KEY	COMMENT
2 and 8	To navigate up and down through the menu list on line at a time
Enter	Selects the line or toggles the option of the line the cursor is on
Esc	Back up one level in the menu
Home	Move cursor to top of the list
End	Move cursor to bottom of the list
Pg Up	Move cursor up on screen
Pg Dn	Move cursor down on screen
BkSpc	Delete character to the left
Shift	Change alpha character selected
Num Lock	Change to numeric entry
Del	Delete
Ins	Insert/change graph setup
Graph	Graph

In any case the keyboard display is self-explanatory because of its menu navigation. It is possible to check data and to run and stop a program or to access the file system on the CPU as well as on the CF Card. Furthermore it can be used to check the ports and the status and to modify the configuration and the settings of the logger.

NOTE: **For further instructions please read section CR1000KD: Using the Keyboard Display of the CR1000 manual.**

Ethernet and CompactFlash Module - NL115

Campbell Scientific's NL115 Ethernet/CompactFlash Module provides two useful capabilities. It enables 10baseT Ethernet communications and stores data on a removable CF-Card. So it is possible to communicate over the local network of the BGC-FTIR-Container, respectively via TCP/IP.

To remove a card, press the control button on the NL115. The datalogger will transfer any buffered data to the card and then power it off. The status LED will turn green when it is OK to remove the card. The card will be reactivated after 20 sec if it is not removed.

Figure 1.29: Ethernet and CompactFlash Module - NL115

More important is the use of data transfer via FTP. The calibration factors and constants which transform the signals into real units are stored on the CF-Card. This makes it possible to modify them without a need to access the main program on the CPU. For details see section 1.3.3 on page 39.

When you are connected through a ethernet line you can also visit the homepage of the datalogger to check the latest records or the status.

http://IP

- IP Adress = 10.3.9.60

<u>NOTE:</u> **Removing a card while it is active can cause grabled data and can actually damage it. Do not switch off the datalogger power if a card is present and active.**

1.3.3 Programming

To modify any parameter via FTP the basic need is to access the file system of the datalogger. You can do so by opening a standard browser and using the following FTP-Adress:

ftp://UserName:Password@IP

- User Name = BGCJena
- Password = ftp
- IP Adress = 10.3.9.60

Now you can access the files on the CPU and the CF-Card by selecting the appropriate folder. You can also access with the CR1000KD. In that case you don't need a PC or a connection to the local network of the BGC-FTIR-Container.

Multiplier and Offsets

To modify a multiplier or an offset you have to open the file **Const.CR1** on the CF-Card of the Datalogger CR1000. Actually there are two possibilities to make the file accessible. The first is to use the keyboard display CR1000KD.

1. Select "**Home**", background light should flash.
2. Select "**File**", confirm with "Enter".
3. Select "**Edit**", confirm with "Enter".
4. Select "**Crd**", confirm with "Enter" to access CF-Card.
5. Select "**Const.CR1**", confirm with "Enter".
6. Search for the parameter which should be modified.
7. Press "**NumLock**" for activating the edit-modus, enter the value.
8. Exit with "**Esc**", confirm settings.

NOTE: **Don't forget to power up the Dalalogger CR1000 to activate the new seetings.**

You can also modify via FTP using a standard browser. Assure, that there is a connection from the Compact/Flash Module Nl115 to your PC or laptop.

1. Open a browser and access the file system via: **"ftp://BGCJena:ftp@10.3.9.60"**
2. Select **"Crd"** directory and choose the file **"Const.CR1"**.
3. Search for the parameter which should be modified and save file.

NOTE: **Don't forget to power up the Dalalogger CR1000 to activate the new seetings.**

Power-Up Function

The key to the CF power-up function is the **powerup.ini** file, which contains a list of command lines. At power-up, the **powerup.ini** command line is executed prior to compiling the program. The **powerup.ini** is created with a text editor and the syntax is very simple.

Command,File,Device

- Command = numeric command according to table
- File = file on CF-Card associated with the action
- Device = the device to which the associated file will be copied to. (CPU/CRD)

Command	Description
1	Run Always, preserve data files
2	Run on power up
5	Format
6	Run now, preserve CF data files
9	Load OS (File=.obj)
13	Run always, erase CF data files now
14	Run now, erease CF data files now

The **powerup.ini** is always copied to the CF-Card with the associated files for proceeding the action. See section A.3 on page 52 for the default file.
At power-up this file will copy the program on the CF-Card to the CPU of the datalogger for running immediately. Data on the CF-Card will be preserved. The new data will be simply added to the old tables if there are no changes in saving of data. Otherwise the data will be stored in new tables.

NOTE: **Do not use editors like WordPad, because it will attach header informations to the file causing it to abort. Check the file with the CR1000KD to see what the CR1000 actually sees.**

1.4 Wiring Panel

There are a couple of plug connections to receive accurate signals at the Datalogger and the SPS. The following tables give proper instructions about connecting the sensors and its information flow for data acquisition.

1.4.1 Sensor <-> Box

Sensor	Wire	Comment
Wind Speed 14557	Sensor 1 - Blue (High)	Block A - Pin 01
	Sensor 1 - Black (Low)	Block A - Pin 02
	Sensor 1 - Brown (24V +)	Power (24V +)
	Sensor 1 - White (-)	Power (-)
	Sensor 2 - Blue (High)	Block A - Pin 03
	Sensor 2 - Black (Low)	Block A - Pin 04
	Sensor 2 - Brown (24V +)	Power (24V +)
	Sensor 2 - White (-)	Power (-)
Temp./Humid. KPC 1/6-ME	Sensor 1 - Black (High)	Block A - Pin 05
	Sensor 1 - Orange (Low)	Block A - Pin 06
	Sensor 1 - Yellow (High)	Block A - Pin 07
	Sensor 1 - Green (Low)	Block A - Pin 08
	Sensor 1 - Red (24V +)	Power (24V +)
	Sensor 1 - Brown (-)	Power (-)
	Sensor 1 - Yellow/Green	- Not Connected -
	Sensor 2 - Black (High)	Block A - Pin 09
	Sensor 2 - Orange (Low)	Block A - Pin 10
	Sensor 2 - Yellow (High)	Block B - Pin 01
	Sensor 2 - Green (Low)	Block B - Pin 02
	Sensor 2 - Red (24V +)	Power (24V +)
	Sensor 2 - Brown (-)	Power (-)
	Sensor 2 - Yellow/Green	- Not Connected -
Precipitation 15152	Wire 1 - White (24V +)	Power (24V +)
	Wire 2 - Brown (-)	Power (-)
	Wire 3 - Green (A)	Block B - Pin 03
	Wire 4 - Yellow (W)	Block B - Pin 04
	Wire 5 - Grey (R)	- Not Connected -
Precipitation 15153	Wire 1 - Brown (24V +)	Power (24V +)
	Wire 2 - Black (-)	Power (-)
	Wire 3 - Not Connected -	- Not Connected -
	Wire 4 - White (W)	Block B - Pin 05
	Wire 5 - Blue (R)	Block B - Pin 06

1.4.2 25 Pin D-Sub (Logger) <-> 40 Pin Connector (Box)

25 Pin D-Sub	40 Pin Connector	Comment
Pin 01	Block A - Pin 01 - Brown	Wind Speed 14557 1 (High)
Pin 02	Block A - Pin 02 - Yellow	Wind Speed 14557 1 (Low)
Pin 03	Block A - Pin 03 - Brown	Wind Speed 14557 2 (High)
Pin 04	Block A - Pin 04 - Green	Wind Speed 14557 2 (Low)
Pin 05	Block A - Pin 05 - Brown	Humid. KPC 1/6-ME 1 (High)
Pin 06	Block A - Pin 06 - Blue	Humid. KPC 1/6-ME 1 (Low)
Pin 07	Block A - Pin 07 - Brown	Temp. KPC 1/6-ME 1 (High)
Pin 08	Block A - Pin 08 - Purple	Temp. KPC 1/6-ME 1 (Low)
Pin 09	Block A - Pin 09 - Brown	Humid. KPC 1/6-ME 2 (High)
Pin 10	Block A - Pin 10 - Grey	Humid. KPC 1/6-ME 2 (Low)
Pin 11	Block B - Pin 01 - Brown	Temp. KPC 1/6-ME 2 (High)
Pin 12	Block B - Pin 02 - White	Temp. KPC 1/6-ME 2 (Low)
Pin 13	Block C - Pin 03 - Black	- Not Connected -
Pin 14	Block C - Pin 04 - Purple	- Not Connected -
Pin 15	Block C - Pin 05 - Black	- Not Connected -
Pin 16	Block C - Pin 06 - Grey	- Not Connected -
Pin 17	Block C - Pin 07 - Black	- Not Connected -
Pin 18	Block C - Pin 08 - White	- Not Connected -
Pin 19	Block C - Pin 09 - Black	- Not Connected -
Pin 20	Block C - Pin 10 - Orange	- Not Connected -
Pin 21	Block D - Pin 01 - Black	- Not Connected -
Pin 22	Block D - Pin 02 - Red	- Not Connected -
Pin 23	Block D - Pin 03 - Black	- Not Connected -
Pin 24	Block D - Pin 04 - Brown	- Not Connected -
Pin 25	Block D - Pin 05 - Orange	- Not Connected -

1.4.3 9 Pin D-Sub (SPS) <-> 40 Pin Connector (Box)

9 Pin D-Sub	Wire	Comment
Pin 01	Block B Pin 03 - Brown	Precipitation 15152 (A)
Pin 02	Block B Pin 04 - Orange	Precipitation 15152 (W)
Pin 03	Block B Pin 05 - Brown	Precipitation 15153 (W)
Pin 04	Block B Pin 06 - Red	Precipitation 15153 (R)
Pin 05	Block B Pin 07 - Black	- Not Connected -
Pin 06	Block B Pin 08 - Yellow	- Not Connected -
Pin 07	Block B Pin 09 - Black	- Not Connected -
Pin 08	Block B Pin 10 - Green	- Not Connected -
Pin 09	Block C Pin 01 - Black	- Not Connected -

1.4.4 25 Pin D-Sub <-> Datalogger CR1000

25 Pin D-Sub	Datalogger	Comment
Pin 01 - Brown	SE 05 (DIFF 3)	Wind Speed 14557 1 (High)
Pin 02 - Yellow	SE 06 (DIFF 3)	Wind Speed 14557 1 (Low)
Pin 03 - Brown	SE 07 (DIFF 4)	Wind Speed 14557 2 (High)
Pin 04 - Green	SE 08 (DIFF4)	Wind Speed 14557 2 (Low)
Pin 05 - Brown	SE 09 (DIFF 5)	Humid. KPC 1/6-ME 1 (High)
Pin 06 - Blue	SE 10 (DIFF 5)	Humid. KPC 1/6-ME 1 (Low)
Pin 07 - Brown	SE 13 (DIFF 7)	Temp. KPC 1/6-ME 1 (High)
Pin 08 - Purple	SE 14 (DIFF 7)	Temp. KPC 1/6-ME 1 (Low)
Pin 09 - Brown	SE 11 (DIFF 6)	Humid. KPC 1/6-ME 2 (High)
Pin 10 - Grey	SE 12 (DIFF 6)	Humid. KPC 1/6-ME 2 (Low)
Pin 11 - Brown	SE 15 (DIFF 8)	Temp. KPC 1/6-ME 2 (High)
Pin 12 - White	SE 16 (DIFF 8)	Temp. KPC 1/6-ME 2 (Low)
Pin 13 - Black	- Not Connected -	- Not Connected -
Pin 14 - Purple	- Not Connected -	- Not Connected -
Pin 15 - Black	- Not Connected -	- Not Connected -
Pin 16 - Grey	- Not Connected -	- Not Connected -
Pin 17 - Black	- Not Connected -	- Not Connected -
Pin 18 - White	- Not Connected -	- Not Connected -
Pin 19 - Black	- Not Connected -	- Not Connected -
Pin 20 - Orange	- Not Connected -	- Not Connected -
Pin 21 - Black	- Not Connected -	- Not Connected -
Pin 22 - Red	- Not Connected -	- Not Connected -
Pin 23 - Black	- Not Connected -	- Not Connected -
Pin 24 - Brown	- Not Connected -	- Not Connected -
Pin 25 - Orange	- Not Connected -	- Not Connected -

1.4.5 9 Pin D-Sub Box <-> SPS

9 Pin D-Sub Box	Wire to SPS	Comment
Pin 01	Green	Precipitation 15152 (A)
Pin 02	Yellow	Precipitation 15152 (W)
Pin 03	Grey	Precipitation 15153 (W)
Pin 04	Purple	Precipitation 15153 (R)
Pin 05	Black	- Not Connected -
Pin 06	Brown	- Not Connected -
Pin 07	White	- Not Connected -
Pin 08	Red	- Not Connected -
Pin 09	Blue	- Not Connected -

1.4.6 Sensor <-> Datalogger CR1000

Sensor	Wire	Comment
Temp. Probe 107	Sensor 1 - Red (Temp. Signal)	SE 01
	Sensor 1 - Black (Excitation)	EX 01
	Sensor 1 - White (Signal Ground)	Ground
	Sensor 1 - Clear (Shield)	Ground
	Sensor 2 - Red (Temp. Signal)	SE 02
	Sensor 2 - Black (Excitation)	EX 01
	Sensor 2 - White (Signal Ground)	Ground
	Sensor 2 - Clear (Shileld)	Ground
Pyrano. CMP3	Sensor 1 - Red (High)	SE 03 (DIFF 2)
	Sensor 1 - Blue (Low)	SE 04 (DIFF 2)
	Sensor 1 - Black (Shield)	Ground
Press. PTB210	Sensor 1 - White (RX)	C 1 - TX (COM 1)
	Sensor 1 - Green (TX)	C 2 - RX (COM 1)
	Sensor 2 - White (RX)	C 3 - TX (COM 2)
	Sensor 2 - Green (TX)	C 4 - RX (COM 2)
	Connection Box - Red (12V +)	Power Out - 12V +
	Connection Box - Black (Ground)	Power Out - Ground
Temp./Humid. CS215	Sensor 1 - Red (12V +)	Power Out - 12V +
	Sensor 1 - White (Ground)	Power Out - Ground
	Sensor 1 - Black (Ground)	Power Out - Ground
	Sensor 1 - Green (Signal)	Control Port 5
	Sensor 1 - Clear (Ground)	Shield
	Sensor 2 - Red (12V +)	Power Out - 12V +
	Sensor 2 - White (Ground)	Power Out - Ground
	Sensor 2 - Black (Ground)	Power Out - Ground
	Sensor 2 - Green (Signal)	Control Port 7
	Sensor 2 - Clear (Ground)	Shield

1.4.7 Power Supply - Box

4 Pin Plug Connection	Wire	Comment
Pin 01	Grey	Power (24V +)
Pin 02	Black	Power (-)
Pin 03	Brown	- Not Connected -
Pin 04	Yellow/Green	- Not Connected -

A.1 CRBasic - Weather Station

```
'PROGRAM:
'WEATHER STATION BGC-FTIR CONTAINER
'AUTOR:
'Hendrik Zoephel (MPI-BGC, Jena, Germany)
'DATALOGGER AND PERIPHERALS:
'CR1000/NL115
'DATALOGGER SETTINGS:
'Logger IP Adress: 10.3.9.60
'Subnet Mask: 255.255.255.0
'IP Gateway: 10.9.3.1
'INSTRUMENTATION:
'temperature: 2 x T107 (Campbell)
'wind speed: 2 x 14577 (Lambrecht)
'humidity and temp.: 2 x KPC 1/6-ME (Galltec)
'humidity and temp.: 1 x CS215 (Campbell Sci.)
'global radiation: 1 x CMP3 (Kipp&Zonen)
'atmospheric press.: 2 x PTB210 (Vaisala)
'humidity/temerature: 2x CS215 (Campbell Sci.)
'CHANNEL USAGE:
'SE1,2: 2 x T107
'EX1:  2 x T107
'DIFF2: CMP3
'DIFF3,4: 2 x 14577
'DIFF5: KPC 1/6-ME (humidity)
'DIFF6: KPC 1/6-ME (humidity)
'DIFF7: KPC 1/6-ME (temperature)
'DIFF8: KPC 1/6-ME (temperature)
'COM1,2: 2 x PTB210
'C5,7: 2 x CS215
'CALCULATION:
'conversion to real units
'square sum
'PROGRAM PARAMETERS:
'Scan rate: 5 sec
'Avg. period: 60 sec.
'Min., Max. period: 60 sec.
'Square sum period:  60 sec
```

```
'_______________________

'DECLARATIONS
'_______________________
Public TRHData(2)
Public TRHData_2(2)
Public Temp_Indoor(2) As String
Public Humid_Indoor(2) As String
Public TempString As String * 30
Public HumidString As String * 30
Public Temp_FTIR(2)
Public WindSpd_Check(2)
Public WindSpd(2)
Public WindSpd_SQ_1
Public WindSpd_SQ_2
Public N
Public Count
Public Humid(2)
Public Humid_SQ_1
Public Humid_SQ_2
Public Temp(2)
Public Temp_SQ_1
Public Temp_SQ_2
Public Pyrano(1)
Public Pyrano_SQ_1
Public OutString As String * 10
Public AirPress(2) As String * 10
Public AirPress_SQ_1
Public Airpress_SQ_2
Public AirPressString As String * 30
Public AirPressNum(2)

'_________________________UNITS____________________________________

Units Temp_Indoor = deg C
Units Humid_Indoor = % RH
Units Temp_FTIR = deg C
Units WindSpd = m/s
Units WindSpd_SQ_1 = (m/s)^2
Units WindSpd_SQ_2 = (m/s)^2
Units Humid = % RH
Units Humid_SQ_1 = (% RH)^2
Units Humid_SQ_2 = (% RH)^2
Units Temp = deg C
Units Temp_SQ_1 = (deg C)^2
```

```
Units Temp_SQ_2 = (deg C)^2
Units Pyrano = W/m^2
Units Pyrano_SQ_1 = (W/m^2)^2
Units AirPress = hPa
Units AirPress_SQ_1 = (hPa)^2
Units AirPress_SQ_2 = (hPa)^2
'_______________________CONST______________________________________

Include "CRD:Const.CR1"
'____________________OUTPUT SECTION________________________________

'_______TABLE CONTAINER_______

DataTable(Table_Indoor,True,-1)

'_______CARDOUT AS RING_______

'OpenInterval
DataInterval(0,60,Sec,10)
CardOut(0,-1000)

'_______T107_______
Average(2,Temp_FTIR(1),FP2,0)

'_______CS215_______
Average(2,Temp_Indoor(1),IEEE4,False)
Average(2,Humid_Indoor(1),IEEE4,False)

'_______NUMBER OF MEASURED DATA_______
Sample(1,N,FP2)

EndTable

'_______TABLE WEATHER STATION_______

DataTable(Table_Outdoor,True,-1)

'_______CARDOUT AS RING_______
'OpenInterval
DataInterval(0,60,Sec,10)
CardOut(0,-1000)
```

```
'_______TEMP_______
Average(2,Temp(1),FP2,0)
Minimum(2,Temp(1),FP2,0,0)
Maximum(2,Temp(1),FP2,0,0)
Totalize(1,Temp_SQ_1,IEEE4,False)
Totalize(1,Temp_SQ_2,IEEE4,False)

'_______HUMID_______
Average(2,Humid(1),FP2,0)
Minimum(2,Humid(1),FP2,0,0)
Maximum(2,Humid(1),FP2,0,0)
Totalize(1,Humid_SQ_1,IEEE4,False)
Totalize(1,Humid_SQ_2,IEEE4,False)

'_______WINDSPD_______
Average(2,WindSpd(1),FP2,0)
Minimum(2,WindSpd(1),FP2,0,0)
Maximum(2,WindSpd(1),FP2,0,0)
Totalize(1,WindSpd_SQ_1,IEEE4,False)
Totalize(1,WindSpd_SQ_2,IEEE4,False)
'Sample(1,Check1,Boolean)
'Sample(1,Check2,Boolean)

'_______AIRPRESS_______
Average(2,AirPress(1),IEEE4,0)
Minimum(2,AirPress(1),IEEE4,0,0)
Maximum(2,AirPress(1),IEEE4,0,0)
Totalize(1,AirPress_SQ_1,IEEE4,False)
Totalize(1,AirPress_SQ_2,IEEE4,False)

'_______PRYRANO_______
Average(1,Pyrano,FP2,0)
Minimum(1,Pyrano,FP2,0,0)
Maximum(1,Pyrano,FP2,0,0)
Totalize(1,Pyrano_SQ_1,IEEE4,False)

'_______NUMBER OF MEASURED DATA_______
Sample(1,N,FP2)

EndTable

'________________________PROGRAMM__________________________________

BeginProg
```

```
'_______SET COMMUNICATION-PARAMETERS FOR PTB210_______
SerialOpen(Com1,9600,10,0,0)
SerialOpen(Com2,9600,10,0,0)

Scan(5,Sec,0,0)

'_______SEND STRING ".P<cr><lf>" TO PTB210_______
SerialOut(Com1,Command,"",0,100)
SerialOut(Com2,Command,"",0,100)

'_______RECEIVE SERIAL DATA AS STRING FROM PTB210_______
SerialIn(AirPress(1),Com1,100,10,10)
SerialIn(AirPress(2),Com2,100,10,10)

'_______CONVERTING STRING INTO NUMERIC VALUE_______
AirPressString = AirPress(1) + "," + AirPress(2)
SplitStr(AirPressNum(1),AirPressString,",",2,0)
AirPress_SQ_1 = AirPressNum(1) * AirPressNum(1)
AirPress_SQ_2 = AirPressNum(2) * AirPressNum(2)

'_______RECEIVE VALUES, VOLTAGES ARE CONVERTED IN REAL UNITS________
SDI12Recorder(TRHData(),5,"0","R!",1,0)
SDI12Recorder(TRHData_2(),7,"0","R!",1,0)

'_______ALLOCATION OF INDOOR MEASUREMENTS TO STRINGS_______
TempString = TRHData(1) + "," + TRHData_2(1)
HumidString = TRHData(2) + "," + TRHData_2(2)
SplitStr(Temp_Indoor(1),TempString,",",2,0)
SplitStr(Humid_Indoor(1),HumidString,",",2,0)
Therm107(Temp_FTIR(1),2,1,Vx1,0,_50Hz,1,0)
VoltDiff(WindSpd(1),2,mV2500,3,True,0,_50Hz,wind_multiplier,wind_offset)
WindSpd_SQ_1 = WindSpd(1) * WindSpd(1)
WindSpd_SQ_2 = WindSpd(2) * WindSpd(2)
VoltDiff(Humid(1),2,mV2500,5,True,0,_50Hz,humid_multiplier,humid_offset)
Humid_SQ_1 = Humid(1) * Humid(1)
Humid_SQ_2 = Humid(2) * Humid(2)
VoltDiff(Temp(1),2,mV2500,7,True,0,_50Hz,temp_multiplier,temp_offset)
Temp_SQ_1 = Temp(1) * Temp(1)
Temp_SQ_2 = Temp(2) * Temp(2)
VoltDiff(Pyrano(1),1,mV2_5,2,True,0,_50Hz,pyrano_multiplier,pyrano_offset)
Pyrano_SQ_1 = Pyrano * Pyrano
```

```
'_______COUNTER OF MEASURED DATA PER INTERVAL_______
Count = Count + 1
N = Count
If TimeIntoInterval(0,60,sec) Then
Count = 0
EndIf

'_______PUT OVER DATA TO TABLE_______
CallTable(Table_Outdoor)
CallTable(Table_Indoor)

NextScan

EndProg
```

A.2 CRBasic - Input file CONST.CR1

```
'-----------------------

'COMMAND FOR PTB210
'-----------------------

Const = CR = CHR(13) 'carriage return
Const = LF = CHR(10) 'line feed
Const = Command = ".P" + CR + LF

'-----------------------

'MULTIPLIER AND OFFSETS
'-----------------------

Const = wind_multiplier = 0.03125
Const = wind_offset = -12.5
Const = humid_multiplier = 0.1
Const = humid_offset = 0
Const = temp_multiplier = 0.1
Const = temp_offset = -30
Const = pyrano_multiplier = 75.1314800901577
Const = pyrano_offset = 0
```

A.3 CRBasic - powerup.ini

```
6,WMS_FTIR.CR1,CPU
```