Manual for the SEMACH- and SEACH-FG chamber systems

v. 3.1a

The SEMACH-FG (large picture) and the SEACH-FG chamber systems in the field (grassland). The foreground above shows the steering unit with battery backup and data storage; the chamber itself in ecosystem respiration mode is visible behind. The inset at right shows the complete SEACH-FG chamber unit. Data storage and steering unit are in a protected hut.

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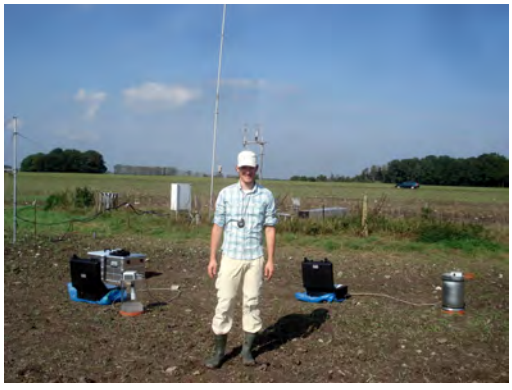


Goals and objectives

Chamber systems are used to analyze soil and/or ecosystem respiration on any type of land cover and independent of season or weather conditions. In their standard mode, just carbon dioxide (CO_2) fluxes can be determined, while measuring fluxes of methane (CH_4) and nitrous gas (N_2O) demand the availability of an appropriate gas chromatograph (and more time). In this manual, "chamber" refers to

- the manually operated SEMACH-FG (**S**oil **E**mission **MA**nual **CH**amber-Freiberg) or
- its automated equivalent SEACH-FG (**S**oil **E**mission **A**utomatic **CH**amber-Freiberg).

The review paper by Oertel et al. (2016) delivers not only methodological information but presents the current understanding of global soil respiration fluxes (references, page 18).

Getting started

Make sure to contact the proper authorities (and land owners) before you start collecting your data. Having permission to complete your research is vital to your operation. It is important to maintain a positive relationship with those in the area you are working with. It makes the experience more pleasant for everyone involved and increases your chances of returning to the area in the future. Maintaining a level of professionalism also puts more credit to your name and to your research.

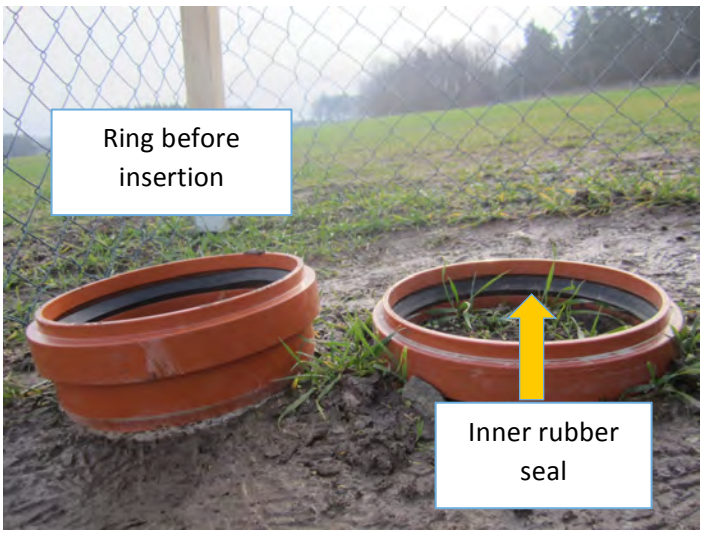
Installation

You need plastic sleeves (= rings: PVC-KGU DN250, or equivalent) with an inner rubber seal as solid base for the chambers. Their internal seal creates a tight fit between ring and chamber, preventing gas from escaping. This guarantees more accurate and reliable data. The tube height should be roughly 105 mm, and will be cut to dimension in a workshop.

Purchase rings with these dimensions:

- Outer diameter 286 mm
- Inner diameter 250 mm
- Wall thickness 6.1 mm

Such cheap yet durable PVC rings are commercially available in many home and hardware stores, and in specialty stores for building and construction equipment: PVC-KGU pipe material DN 250.



The photo at right shows a ring before insertion (l.) and an inserted ring (r.)

Securing the rings into the soil is a simple task, requiring:

- N rings (number N dependent on project goals)
- 1 rubber hammer or equivalent
- 1 level (minimum length 40 cm) or equivalent
- 2 persons

The purpose of these PVC rings is to allow not only for a tight seal between chamber and soil, but also to build a stable base for the chamber systems that can be used many times without further soil disturbance. When installing the rings already, the operator needs to take great care to disturb the soil as little as possible.

With one person hammering the ring gingerly into the ground, the other person holds the ring steady and in place, using the level to maintain proper positioning. By holding the ring steady you reduce shock to the soil. Shockwaves could break the soil (very important under dry or strongly compacted soil conditions). Breaking of soil makes it more difficult to put the ring in place, since the soil will crumble from the mechanical impact.

Once a ring sits firmly in the soil (maximum depth ca. 5 cm; below the rubber seal), the level is used again to control that the ring placement is level; make adjustments as necessary.

It is important to install the rings at least 24 hours before taking your first measurements. Depending on systems dynamic, this time lag may have to be extended (e.g. cold climate zone). This lag time allows the soil to settle and to adjust back to its regular conditions (soil is a living medium).

Soil or ecosystem respiration?

CO_2 fluxes can be separated into three types:

1) Soil respiration includes root, anaerobic and aerobic microbial respiration. Root respiration contributes on average up to 50 % of the total soil respiration, yet may vary between 10–95 %, subject to season and vegetation type (Hanson et al. 2000),
2) Ecosystem respiration additionally includes aboveground plant respiration,
3) Net ecosystem exchange (NEE) is the difference between photosynthesis and ecosystem respiration. A positive NEE indicates a CO_2 source, whereas a negative NEE reveals a CO_2 sink.

If you wish to determine **soil and ecosystem respiration**, make sure that the chamber itself is covered with the padded aluminum foil (aluminum outside) to prevent photosynthetic activity in the chamber.

Should you want to determine net ecosystem exchange (NEE), the cover (padded aluminum foil) needs to be removed. This option is only feasible with short vegetation that does not interfere with the chamber-internal sensors, e.g. lower grass vegetation etc.

Manual Chamber (SEMACH-FG)

The manual chamber is a closed dynamic system, able to measure soil and/or ecosystem respiration on-site based on carbon dioxide (CO_2) as standard. Methane (CH_4) and nitrous oxide gas (N_2O) can be determined by sampling through an interface into appropriate vials (e.g., Exetainers©) and subsequent off-site gas chromatography. The chamber is easily transportable (21 kg for all) and can be used on multiple sites. It is a flexible device to use; yet it does require human direction and supervision.

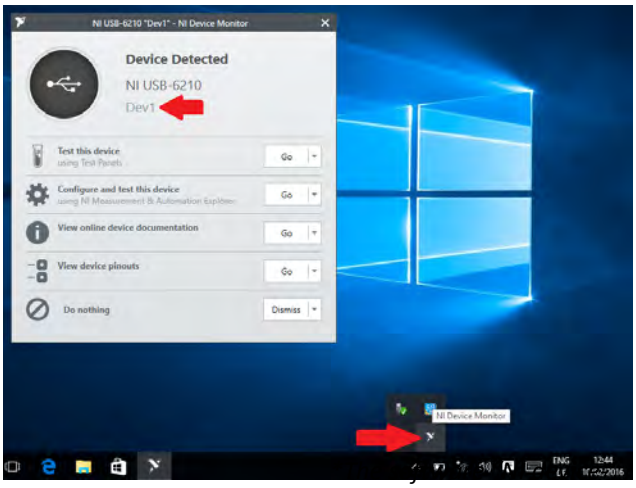
Equipment provided:

- SEMACH-FG System (chamber); 11.7 kg with Alutec transport box
- Power and control box (Peli case); 9.1 kg:
  - ⇒ Laptop and charger
  - ⇒ USB cable
  - ⇒ Power box charger

Downloading the SEMACH-FG program

Setting up the channels

1) Select “Setup” and “Multichannel” tab
2) Under “Channel number” pull down select desired N
3) In the space under “Channel name” enter desired name. This name must be unique in order to be able to receive data display
4) In the “Physical Channel” pull down select “Dev1/ai(N-1)” – see device monitor at right*
5) In the space under “Slope” and “Offset” enter the configuration for the channel for the particular chamber you are using
6) In the space “Designation calibrated unit” enter the appropriate unit
7) Click “Save”
8) Repeat steps 1–7 for each channel
   - ⇒ The standard order of the channels is as follows:
     1. Inside chamber humidity (%rH)
     2. Inside chamber temperature (°C)
     3. Inside chamber pressure (mbar)
     4. Soil moisture (volumetric water content, VWC)
     5. Soil temperature (°C)
     6. CO_2 mixing ratio (≅ concentration) in ppm_v (set to maximum range of 1000 ppm_v)
     7. Outside chamber humidity (%rH)
     8. Outside chamber temperature (°C)
     9. Outside chamber pressure (mbar)
     10. Outside chamber photosynthetically-active radiation (PAR in µmol m^{-2} s^{-1})



manager”, see picture above, can be used to test device settings. You can use various chambers on one computer, forcing each chamber systems to be an individual device.

Downloading and transferring settings

1) To transfer the program configuration of the channels to another computer, select “Export Configuration” under the “Setup” tab and name the file accordingly
2) Transfer file to a secondary computer
3) Open the program and under the “Setup” tab select “Import configuration” and find the appropriate file

Collecting data

Before you leave:

- Checklist to prevent forgetting things
- Charged power box (Peli case)
- Charged laptop and back-up batteries
- Keys for site access (in case that you work at a protected site)

Taking measurements

1) Remove data connector protection lid on the outside of the power box (Peli case) and connect the chamber cord to the power box; make sure the inserts are clean
2) Connect USB to laptop
3) Turn on the power box
4) Remove covers for radiation (PAR) and soil moisture sensors
5) Make sure gas sample chambers are closed (luerlock interface is closed)
6) Fully insert soil temperature (5 cm) and moisture sensors
7) Login into computer
8) Open program “SEMACH-FG”
9) Ensure that the desired channels are listed on the left hand side under the “Multichannel” tab, which shows all activated channels
10) Select “Setup” and ensure the “Enable channel” button is lit yellow for each desired channel; Change channels with “Channel number” arrow
11) Multiple channels can be viewed at the same time under the “Multichannel” tab, while all channels are recording
12) A singular channel can be viewed under the “Singlechannel” tab, while all channels are recording
    a) To change, which single channel is viewed, select the “Setup” tab and simply select the desired channel number under “Channel Number”
13) Under the “Measurement” tab select the folder image on the left hand side of the screen to select where to save the recorded data, and name the file accordingly. This must me done for each individual recording.
14) In the white comment box write the description (e.g.)
    a) Date

b) Ring #
c) Weather
d) Vegetation/Location
e) Trail #

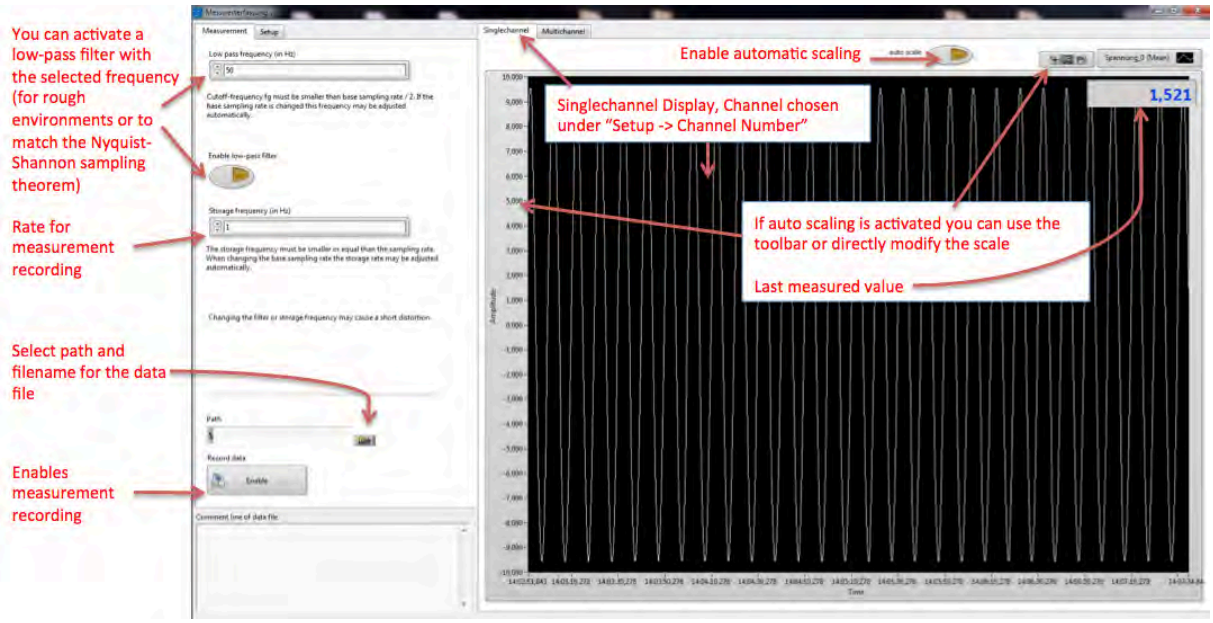
15) To start recording the data, click the “Enable” button
16) Place chamber onto the PVC ring. Make sure it is on straight and tight
17) Record data for N amount of minutes (dependent on project)
18) To stop recording click the same button “Deactivate”
19) Let CO_2 levels return to initial value (take the chamber off the ring and let it vent)
20) Repeat steps 11–17 at least three times for each ring (number of repeated measurements is dependent on the project)
21) Once complete, close program
22) Protect all sensors after use with their covers:
    a) Light (PAR)
    b) Soil moisture
    c) Power box (Peli case) outside connector cover
23) TURN OFF THE POWER BOX
    - If the charge is below “10” make sure to charge the device (Charger can be found in the power box = Peli case)

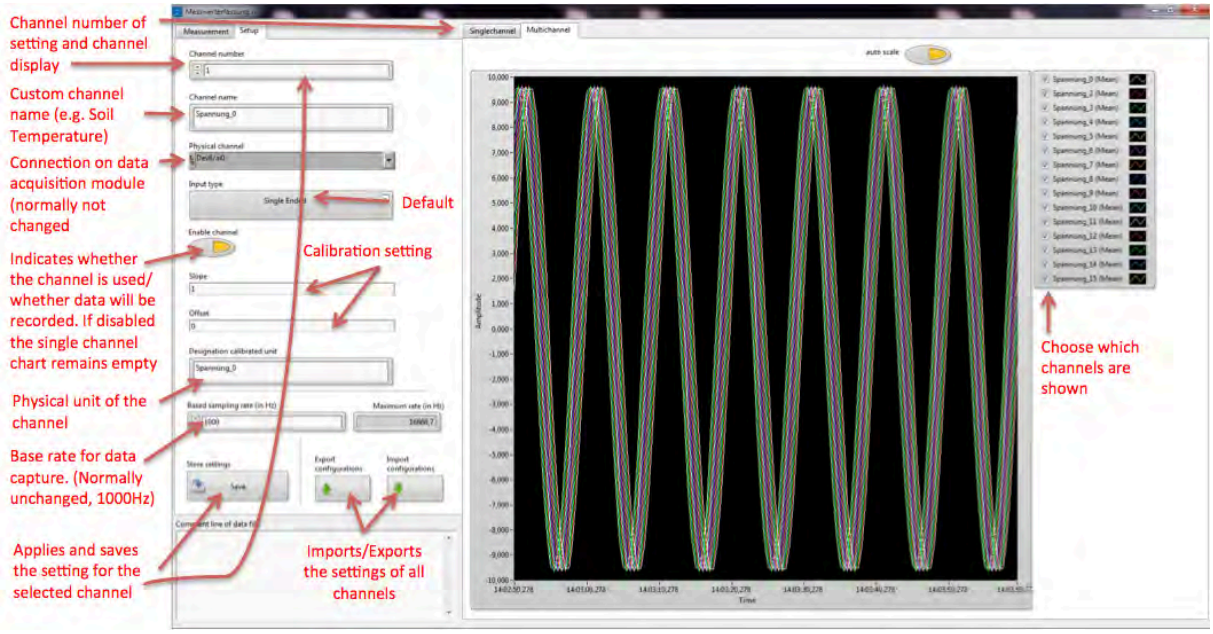
When you leave the site

- Bring equipment, laptop, and power box home, recharge and store safely
- Take garbage back
- Lock site doors, gates, etc. (if you work at a protected site)

Manual chamber program display guide

The following two screen shots show the “Measurement” and “Set-up” menus and describe the individual selection options.





Sampling for methane (CH_4) and nitrous oxide (N_2O)

While determining CO_2 flux rates is relatively fast and straightforward, an additional assessment of CH_4 and N_2O-flux rates demands more time and additional working steps. Each chamber is equipped on the top with a luer-lock interface and valve. This valve is generally closed. When a CO_2 measurement starts after the usual 1-minute lag time, a first gas sample can be taken with a 10 mL syringe (luer-lock system) and a fine needle (0.45 x 25 mm). The syringe is tightly attached to the interface, the valve opened, and a first syringe volume taken up. The valve is closed, the syringe taken off and its gas expelled. The procedure is repeated, but this time, the gas is not expelled but injected with the needle through a (double) septum into an appropriate vial. We recommend 5.9 mL Exetainer® glass vials from the company Labco Limited in Great Britain (Glatzel and Well 2008). The vial is properly labelled and stands for the baseline gas concentrations. When the CO_2 measurement is at its end, this procedure is repeated, giving a second vial. Since both CH_4 and N_2O require considerably longer accumulation rates, the chamber is now not taken off its base (the PVC ring). Instead, further gas sampling takes place in, e.g., 5-minute intervals. A absolute minimum of three gas samples, better five to six gas samples should be taken over the total of 30 minutes to properly represent the gas flux. Thereafter, the chamber will be flushed, and prepared for another cycle.

Automatic chamber (SEACH-FG)

The automatic chamber can be used alternatively to the manual system as a permanent structure working autonomously over many months – provided electricity (grid) and regular maintenance are taken care of. The SEACH-FG automatic flux chamber measures ecosystem respiration (CO_2), but can be programmed to determine methane (CH_4) and nitrous oxide (N_2O) with a direct link to a mobile gas chromatograph. In either configuration, it is a larger system and can only be used realistically at a single location. Moving the equipment is time consuming and more tedious. The location placement might be limiting but the SEACH-FG does not require human assistance and records measurements 24/7, a viable option, e.g. at state monitoring sites.

Equipment provided

- SEACH-FG System (chamber)
  ⇒ Data logger
- Power cable
- USB connection cable
- Laptop/Charger

Placement of SEACH-FG automatic chamber

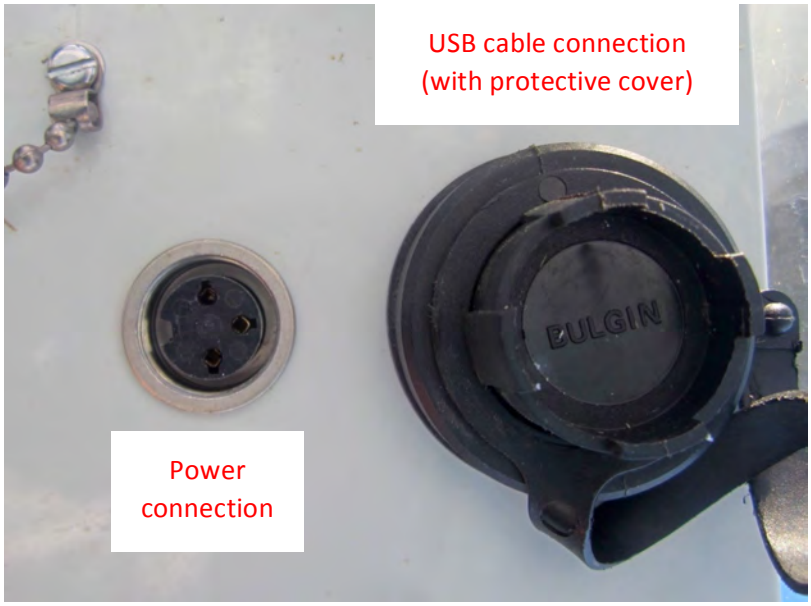
Before you leave

- Checklist to prevent forgetting things
- Charged laptop and back-up batteries
- USB connection cable
- Power cable
- Data logger key
- Keys for site access (in case that you work at a protected site)

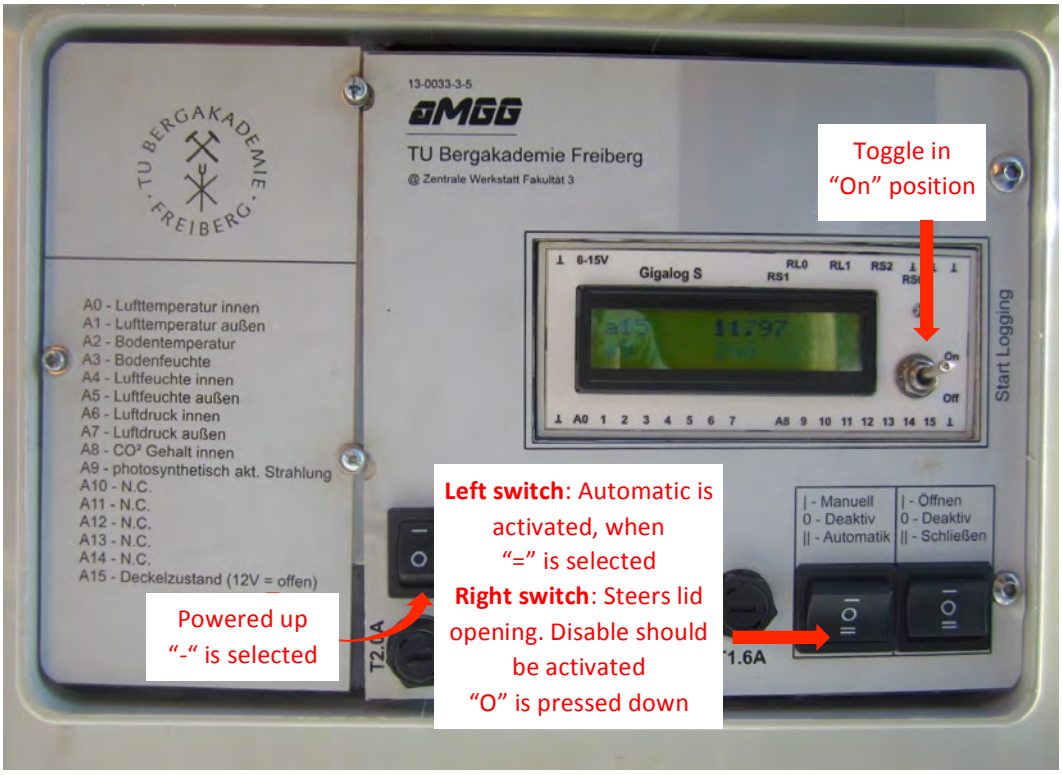
Installation

1. Place chamber onto the PVC ring. Make sure it sits on tight and straight. Fully insert soil temperature (5 cm) and moisture sensors.
2. Connect chamber to power source

The picture (r) shows the power connector (l) and the protected USB data cable connection (r)



3. Use the data logger key to open the box and make sure the switches of the data logger are in the proper position for recording (see picture below)



The picture above shows the various channels (A0 to A15) on the left and in the display window (center r.). Those channels are programmed as follows:

A0:	*Inside air temperature (°C)*
A1:	*Outside air temperature (°C)*
A2:	*Soil temperature (°C)*
A3:	*Soil humidity (= volumetric water content, VWC)*
A4:	*Inside air humidity (%rH)*
A5:	*Outside air humidity (%rH)*
A6:	*Inside air pressure (mbar)*
A7:	*Outside air pressure (mbar)*
A8:	*Inside CO_2 mixing ratio (≅ concentration) in ppm_v*
A9:	*Photosynthetically active radiation (PAR)*
A10–A14:	*not used*
A15:	*Lid status (12 V = open)*

Four switches and two fuse boxes are visible on the right hand side of the data logger panel. Safeguarded with 2.0 Amperes, the left hand side is the main switch (Power on). The two switches to it right drive system status (I = manual, 0 = deactivated, II = automatic) and the chamber lid (I = open, 0 = deactivated, II = close). This switch can override the automatic setting (e.g. in case of a problem).

4. Lock the data-logger cover, when done to protect it from mechanical or weather-related strain.

Changing the SEACH-FG chamber settings

1) Open the data logger and turn it off
2) Remove protective cap of the USB connection port and connect USB cable to the data logger and the laptop
3) Open “Gigaterm”
4) Select “Macros” tab
5) Select “m3” tab
6) Select point “Perform exactly”
   a) Set the seconds tab to “10” and leave the rest as zero
   b) Enter the following equation in the “Command” space
      if a 15>10 rl1=0 wt2000s else rl1=1 wt1000s
      i) This programs the data logger as when to open and close the chamber lid
      ii) 15>10 rl1= 0 is the voltage to open the lid
      iii) rlr=1 is the voltage to close the lid
      iv) wt means “wait”, and the number that follows is the amount of time in seconds it should be in that position. You may adjust this time
      v) In the equation above it is telling the data logger to have the chamber lid open for 2000 seconds and closed for 1000 seconds
   c) Click “Apply”
7) Select point “Without date”
   a) In the “Command” space write the following: “rl0=1”; This tells the data logger what the standards are for the open and the closed lid position
   b) Click “Apply”
8) Turn on the data logger
9) Click the yellow box in the upper left hand corner with the arrow pointing down. This downloads the new changes to the data logger
10) Disconnect the cables and replace the protective covers over the port on the data logger

Daylights Saving Time

1) Remove protective cap of the USB connection port and connect USB cable to data logger and laptop
2) Open “Gigaterm”
3) In the upper left hand corner click the yellow box with a small image of a clock
4) Click the yellow box in the upper left hand corner with the arrow pointing down. This downloads the new changes to the data logger
5) Disconnect the cables and replace the protective covers over the port on the data logger

Collecting data

Before you leave

- Checklist to prevent forgetting things
- Charged laptop and back-up batteries
- Collect USB cord connector
- Data logger key
- Lock site access (in case that you work at a protected site)

Taking measurements

1) Remove protective cap of the USB connection port and connect USB cable to the data logger and the laptop
2) Login into computer
3) On the laptop open “Gigaterm”
4) Make sure the pull down section is on proper “COM” link
5) Check the “Open” box
6) Click the far left arrow (in the yellow box pointing up)
7) Select “Upload” Tab
8) Click “Switch” to select folder
   a) Do not change the file name. Leave it as “gigalog”
9) Make sure “Add File” is selected
10) Click “Start”
11) Once complete uncheck “Open”
12) Close program
13) Close USB port on the data logger

Clearing the data

This clears all data from the automatic chamber. Make sure the data is saved onto the computer before deleting the data.

1) Remove protective cap of the USB connection port and connect USB cable to the data logger and the laptop
2) Login into computer
3) On the laptop open ‘aMGG Formator”
4) Make sure the pull down section is on “COM 3”
5) Click “Link”
6) Click “SD-Format Card”

When you leave

- Bring back laptop, USB cable, and data logger key
- Take garbage
- Lock site (if you work at a protected site)

Cleaning and maintenance

Keeping the chamber clean ensures an organized workspace and aids the equipment to work efficiently for years to come. It is important to clean any soil, which may be stuck to the bottom off the chamber, and both the soil temperature and moisture sensors. Clean the PAR sensor gingerly each time with a soft cloth. It is also necessary to make sure that the inserts for the flux chamber cord is clean and dry. A dry cloth or paper towel is sufficient for cleaning. The chamber itself (acrylic glass) needs to be cleaned (wiped with a humid microfiber cloth), whenever it is visibly dirty and its translucence inhibited.

Along with cleaning comes the equipment maintenance. The chamber needs to be stored somewhere safe after fieldwork and preferably in its original hard box. The soil moisture and temperature sensors are the most fragile and exposed parts of the chamber. Therefore when storing the chamber, ensure the cables have the proper protective covers and are placed neatly on top of the chamber, not underneath.

Make sure to air all equipment prior to storage and to fully recharge the batteries.

All equipment should be tested in a workshop or lab prior to field use and all functions tested for full operability. Make sure that batteries are removed when the equipment is not used for a while (weeks) and stored properly. Maintain the capacity of rechargeable batteries according to their maintenance plan.

Troubleshooting

Manual Chamber

Problem	Possible Solutions
Program is not reading any values	• Disconnected and reconnect the cables • Turn the program on and off • Turn the power box on and off • Restart the computer • Connect the cables to a different USB port on your computer • Make sure the equipment is charged
Program delivers obscure data	• Disconnect and reconnect the cables • Turn the program on and off • Turn the power box on and off • Restart the computer • Connect the cables to a different USB port of your computer • Make sure the equipment is charged • If none of the above tips solves the problem, the equipment might be broken and needs to be turned in for repair
Measuring in the winter (cold) season	• Bring tools to dig holes into the frozen soil for the sensors. Prevent bending or breaking the sensors by force • The rings can collect snow and ice during the winter months. Remember to bring a tool to help break up ice inside the ring to make sure the chamber can be properly secured
Measuring under summer (hot and humid) conditions	• Take a knife along to assist ring positioning in root-rich soils • Make sure to protect the netbook from direct exposure to direct sun and from humidity (rainfall) – use an umbrella.

Automatic Chamber

Problem	Possible Solutions
"COM 3" option does not appear in pull down menu (Port number may vary and could be COM1, COM2, …, depending on computer used)	• Insert USB into another computer port • Disconnect and reconnect the cable • Disconnect the cable connected to the chamber, rotate it by 180 degrees and reinsert • Close and reopen the program • Turn off the automatic chamber, while downloading the data
"Error" appears as you try to download the data	• Make sure the file name has not been changed from "gigalog" • Turn off the automatic chamber, while downloading the data
Chamber turns off unexpectedly	• Restart the chamber by turning it on and off • If this problem continues, turn the automatic chamber in a workshop to have it repaired
Lid does either not close or open – or moves only part way	• High likeliness that the battery in the power box is on low capacity.

The automatic chamber with its lid almost open

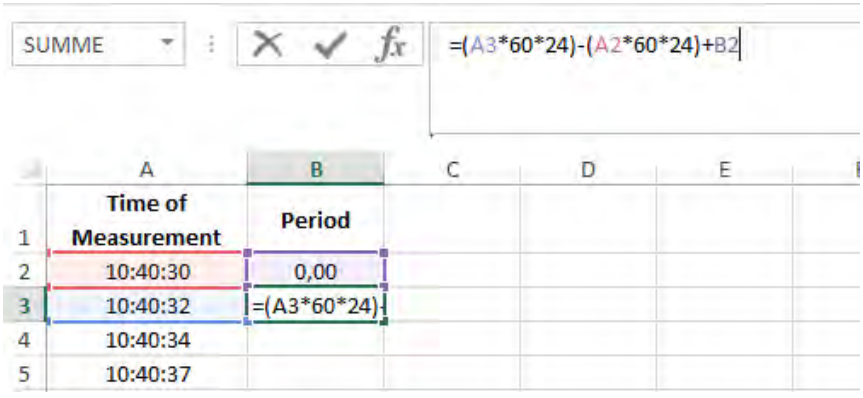
Analyzing the data

When looking at the collected data on the computer, it is important to know how to organize them. It is best to open your data using MS-Excel©. Upon opening this program, you will notice that the columns are not labeled.

From left to right the labels for the columns are

- Time of measurement
- Inside humidity (% rH)
- Inside temperature (°C)
- Inside pressure (mbar)
- Soil moisture (VWC, rH%)
- Soil temperature (°C)
- CO_2 (ppm_v)
- Outside humidity (%rH)
- Outside temperature (°C)
- Outside pressure (mbar)
- Radiation

In order to analyse the data, an additional column has to be created. This should be labeled “Period” to show the length of time the measurements were recorded for; therefore the first value should be zero. To fill the rest of the column use the “Time of Measurement” and the following equation (Remember to make sure “Time of Measurement” is in the format of *Time* and “Period” is in the format of *Standard*). = [Time of Measurement (N)*24 hrs*60 mins] – [Time of Measurement (N+1)*24 hrs*60 mins] + Period (N+1)



It is also important to remember to delete the first minute of your data in order to get more accurate and representative results.

Flux calculation

We use the simplified CO_2 flux calculation method (Leppin 2015) because there is commonly an underestimation of the CO_2 levels by 10 to 30 percent. This flux can be caused from altered diffusion gradients, altered pressure inside the chamber, installation, and temporal variability (Thienelt 2007). The level of CO_2 flux per time unit within the chamber is determined by linear regression.

$$F_{CO_2} = \frac{\Delta V_{CO_2} * V_{ch} * P_{Ch} * 100}{60 * R * (T_{Ch} + 273{,}15) * A_{Ch}}$$

F_{CO2} = CO_2 flux (µmol m^{-2} s^{-1})

V_{Ch} = Volume of chamber (m^3)

ΔCO_2 = Change of CO_2 mixing ratio (ppm_v/min)

P_{Ch} = Air pressure inside the chamber (mbar)

R = Universal gas constant (KJ mol^{-1} K^{-1})

T_{Ch} = Temperature inside the chamber (°C)

A_{Ch} = Base area of the chamber system (m^2)

References

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Impressum

This manual has been complied and quality tested by Erik Börner, Thomas Drauschke, Kamal Zurba, Jörg Matschullat, Laura Medeiros Braga, Cornelius Oertel, Erin Ritchie, Spela Preradović Hlede and Sophie von Fromm in January and February 2016

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