Measurement of Greenhouse Gases

Air-Conditioned Perspex Chambers for the Measurement of Soil Respiration and Trace Gases in Undisturbed Plant Populations

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Various anthropogenic causes contribute to the increasing greenhouse effect. Carbon dioxide from agricultural areas plays a significant role in this respect. Usually, chamber methods are used for the quantification of CO_2 from the plant-soil system. This leads to problems caused by chamber effects which are primarily seen in a temperature increase and a reduction in the amount of photosynthetically active light; therefore, a measuring system was developed during the present investigation which allows these effects to be minimized. These measurements are based on the closed measuring chamber developed in Hohenheim, which, during the present study, was extended to comprise Perspex covers and air conditioning.

Keywords
Carbon dioxide, greenhouse gases, air-conditioned Perspex chambers, soil respiration

Introduction

The trace gas carbon dioxide accounts for approximately 50% of the global greenhouse effect. Within the past 250 years, the CO_2 content of the air has grown from 280 ppm to a current 355 ppm. This value is subject to both spatial and temporal variation [1]. The most important anthropogenic reasons for the increase must be seen in the clearing of forests, the combustion of fossil energy carriers, and the intensification of land use. Especially the quantification of the CO_2 emissions from agricultural areas still requires significant research efforts [4]; consequently, a field trial was set up as a bifactorial split system near Hohenheim University as part of the DFG-funded research group „Measurement, Reduction, and Modelling of Greenhouse Gases in Agricultural Systems". In this trial, different systems of land use are being studied with regard to varying CO_2 fluxes.

The field trial was conducted at the Heidfeldhof experimental site. The field plan (**figure 1**) shows the arrangement of the plots and the infrared gas analyzers.

Four variants are being examined during this field trial: two tillage systems (inverting - non-inverting) and two variants of crop rotation (with legumes - without legumes). For inverting tillage, a plough is used, while only a cultivator or a rotary cultivator are employed for non-inverting tillage, leading to relatively superficial cultivation. Crop rotation 1 (winter rape - horse bean - winter wheat - grass/clover) is supposed to simulate a farm which supplies nitrogen through intermediate crops rich in legumes and organic fertilizers. Crop rotation 2 (winter rape - oat - winter wheat - mustard - sugar beet - winter wheat) does not include any legumes and exclusively relies on mineral fertilizer. During these variants, which are repeated four times each, long-term measurements of CO_2, N_2O, and CH_4 are taken.

For the measurement of CO_2, the chambers are closed 6 times a day (every 4 hours) for 10 minutes, and one measurement value is recorded per minute. The CO_2 concentrations in the individual chambers are determined directly on the experimental field using infrared gas analyzers (Edinburgh Sensors Co. or Licor LI 6252). The arrangement of the infrared gas analyzers shows that groups of four chambers are controlled by one switch box each. All chambers can be closed and opened independently. Since, however, only one CO_2 infrared gas analyzer is available per switch box, the chambers A1, B1, C1, and D1 as well as A2, B2, C2, and D2 etc. are closed simultaneously during the measurements. In addition to this main trial, supplementary experiments are conducted on the remaining field area. During these experiments, different fertilizers, tillage implements, etc. are varied. A further additional trial is the measurement with four of the further developed Hohenheim measuring chambers to determine of the systematic error of the polyethylene chambers.

Chamber effects, i.e. the development of a microclimate within the chamber, cause problems during chamber measurements.

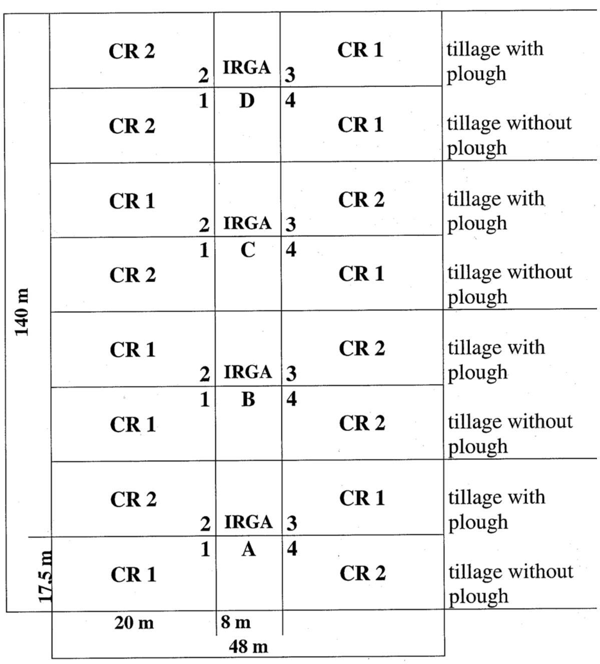

Figure 1: Field plan of the Heidfeldhof experimental site
(FF 1 = crop rotation without legumes, FF 2 = crop rotation with legumes, IRGA = infrared gas analyzer, A-D: repetitions, 1-4: chamber positions)

The most important chamber effects are an increase in temperature and humidity, as well as a reduction in the amount of photosythetically active light. During the measurement with the Hohenheim chamber out of polyethylene, a substantial temperature increase and the cessation of assimilation were observed after a few minutes. The measurements of soil respiration were distorted by this effect. For this reason, the Hohenheim measuring chamber was modified so that the mentioned chamber effects were minimized significantly.

The old measuring chamber (**figure 2**) consists of a steel base frame. The recessing sheet defines an experimental area of one square meter. The chamber (figure 2: plastic chamber) consists of 2 mm, milky PE and is placed upon the recessing sheet using an electric lifting cylinder which moves the swivel arm. A detailed description of the measuring chamber can be found in reference [2]. The entire system of 16 measuring chambers is controlled by a PC.

Thus far, these measuring chambers have been used exclusively with covers out of polyethylene [2, 3]. Especially when measuring carbon dioxide, this causes the measurement values to be impaired considerably (**figure 3**).

At the beginning, a decrease in CO_2 concentration can be observed, i.e. assimilation occurs: CO_2 is absorbed by the plants. Immediately after the chambers have been closed, assimilation is inhibited mainly by the reduction of photosynthetically active light. The gradually beginning additional influence of the temperature increase causes the slope to flatten out after 10 minutes. Due to these effects, the photosynthetic capacity of the plants is restricted significantly. If the chambers remain closed, the plants cease assimilation. After 15 minutes, the slope is nearly zero. Since the absorption of carbon dioxide by the plants depends on radiation as well as temperature, the properties of the chamber material are of great importance for the plausibility of the measurement values. In order to avoid the chamber effects exerting too strong an influence on the measurement values, it is necessary that 1) chambers be used which are largely transparent for radiation and 2) an increase in temperature be avoided by means of air conditioning.

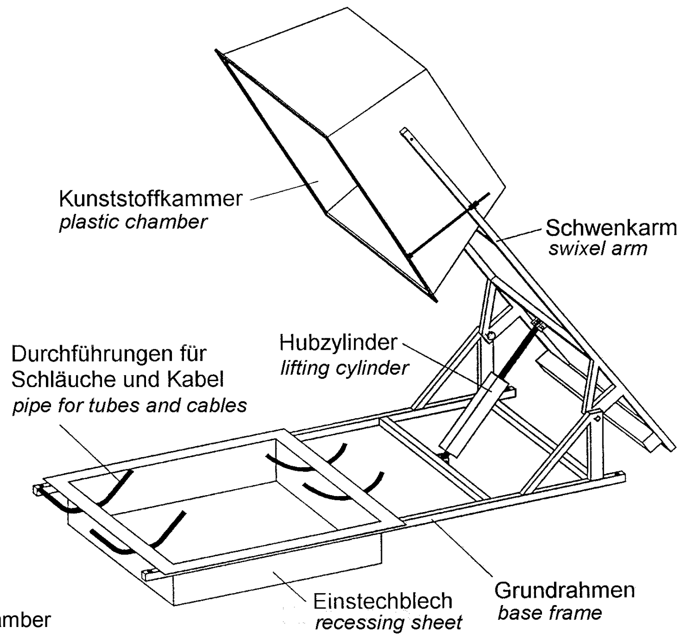

Figure 2: Hohenheim Chamber

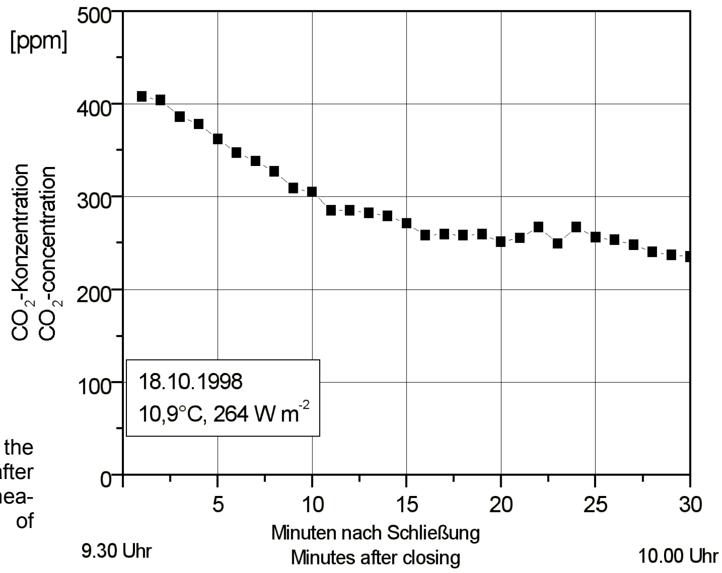

Figure 3: Change of the CO_2-concentration after 30 min closing time measured with chamber of polyethylene

Modification of the Measuring Chamber

When modifying the measuring chambers, PE was replaced with perspex, letting 90 to 96% of the radiation through; therefore, air conditioning became necessary. Figure 4 shows a view of the air conditioner - the casing has been removed - (**figure 4a**) and a detail view from above (**figure 4b**). For air conditioning, the air circulates from the chambers through a temperature- and UV-resistant, flexible PU hose to a conventional air conditioner (Elta company) and back (2a, 2b). The space within the air conditioner through which chamber air flows - in the figure the upper part with 1,2,3 - was sealed, so that no air exchange with outside air can take place even within the air conditioner. In addition, the air conditioner is protected by a frost guard, which turns itself on at temperatures below 5 °C. It cannot be seen in the figure because it is attached to the door.

The air is cooled with the aid of a temperature difference circuit (TDC), which was built into the air conditioner (4). The radial ventilator (1), which guarantees circulation between the chamber and the air conditioner, had to be sealed at the shaft to insulate it from the lower part of the air conditioner. This caused the motor (5) to overheat. For this reason, an additional ventilator (6) was installed.

The circuit diagram in **figure 5** shows the wiring of the TDC to the air conditioner. The TDC compares the ambient temperature with the temperature in the chamber and switches the air conditioner on when the difference reaches 2 K. Five minutes before the measurement begins, the TDC is activated by the control program. The set value of the chamber temperature is 2 K below the actual value provided by the outside temperature sensor. This causes the air conditioner to pre-run so that its full cooling capacity is available immediately after the chambers are closed.

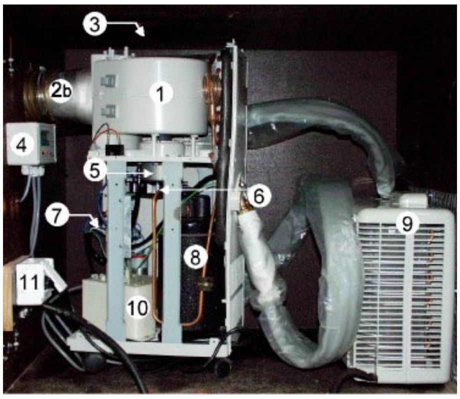

Figure 4a: Side view of air conditioner

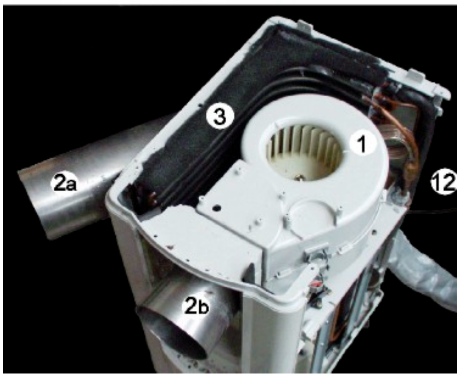

Figure 4b: view from above of air conditioner
(1 radial ventilator, 2a intake hose adapter, 2b output hose adapter, 3 cooling aggregate, 4 circuit for temperature differences, 5 radial ventilator motor, 6 additional cooling ventilator for motor, 7 luster terminal (covered), 8 compressor, 9 heat exchanger, 10 condense-water tank, 11 230 V connection, 12 expansion valve)

The entire system is controlled with the aid of a PC, which controls the switch boxes to which four measuring chambers each are connected. The components of the measuring system with the further developed Perspex chambers are shown in **figure 6**. The electric lifting cylinder, which had been used thus far, was replaced with a pneumatic cylinder. Four measuring chambers are run with a compressor.

Results

At an outside temperature of approximately 30°C (**figure 7**), the temperature in the polyethylene chambers increases by 10 K to 40°C after 10 minutes. The temperature in the Perspex chambers grows by almost 20 K, while in the air-conditioned Perspex chambers no difference can be measured between the temperature in the chambers and the outside temperature.

If radiation is considered, it can be shown that at 650 W m^{-2} radiation in the PE chambers is almost 40% lower, while only very small light losses occur in the

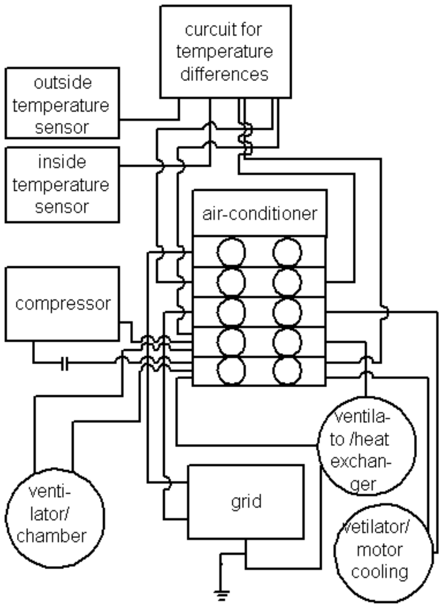

Figure 5: Wiring of air-conditioner with temperature difference circuit

Perspex chambers. These differences also apply when the CO_2 concentration is measured in PE and Perspex chambers (**figure 8**).

The course of the CO_2 flux measured with the two chamber systems (**figure 9**) exhibits a significant difference depending on the time of the day. At higher radiation, the measured CO_2 values in the perspex chambers are lower, i.e. this measuring system allows the plants to absorb more CO_2, and their photosynthetic capacity is influenced less. Since the conditions in the air-conditioned perspex chambers approximately correspond to the ambient conditions, these values can be considered real. In contrast to this, measurements with the PE chambers used thus far lead to soil respiration being significantly overestimated in the long run due to the reduction of assimilation. As expected, no differences between the individual variants can be determined at night when radiation is nearly zero because the chamber effects only occur during the day to a relevant extent.

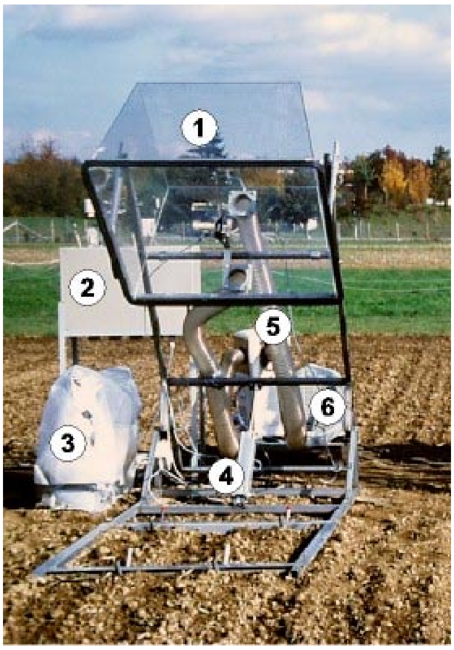

Figure 6: Components of the measurement system
(1 perspex chamber, 2 switch box, 3 compressor, 4 pneumatic lifting cylinder, 5 PU-hose, 6 air conditioner)

Conclusions

The Hohenheim Chamber System has been developed for the registration of the climate-relevant trace gases N_2O, CH_4, and CO_2 from soils. It was shown that during CO_2 measurements CO_2 balancing errors may occur due to the microclimate which develops in the chambers. The further developed air-conditioned Perspex chambers enable these errors to be minimized to a very large extent because the conditions in the chambers are nearly the same as those outside. These measuring chambers thus provide a good possibility for a reliable measurement of the CO_2 fluxes in plant populations.

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Acknowledgements
We would like to thank the DFG for funding this research project, as well as our colleague S. Richter for the design and the construction of the air-conditioned Perspex chambers.

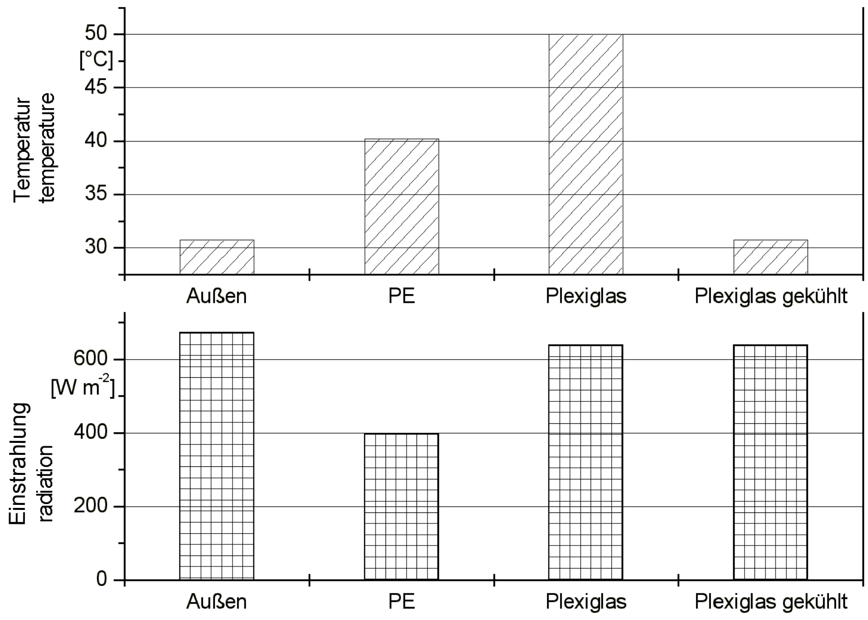

Figure 7: Change of temperature and radiation under the chambers after a closing time of t_s=10 min

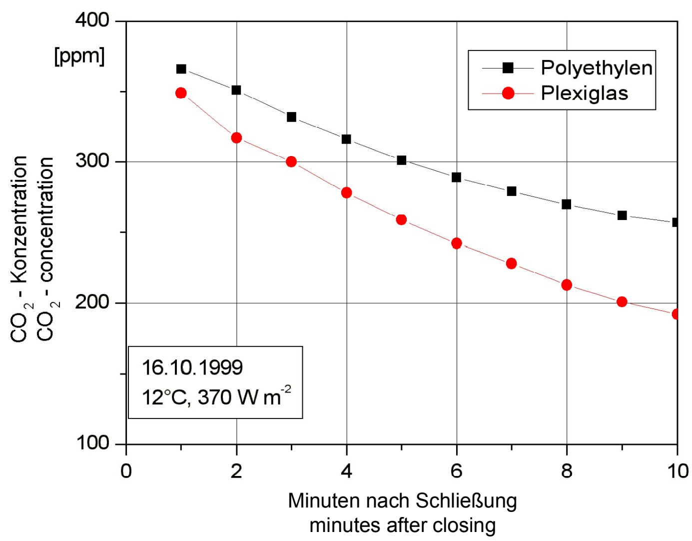

Figure 8: Run of CO_2-concentration under PE and perspex chambers after a closing time of t_s=10 min

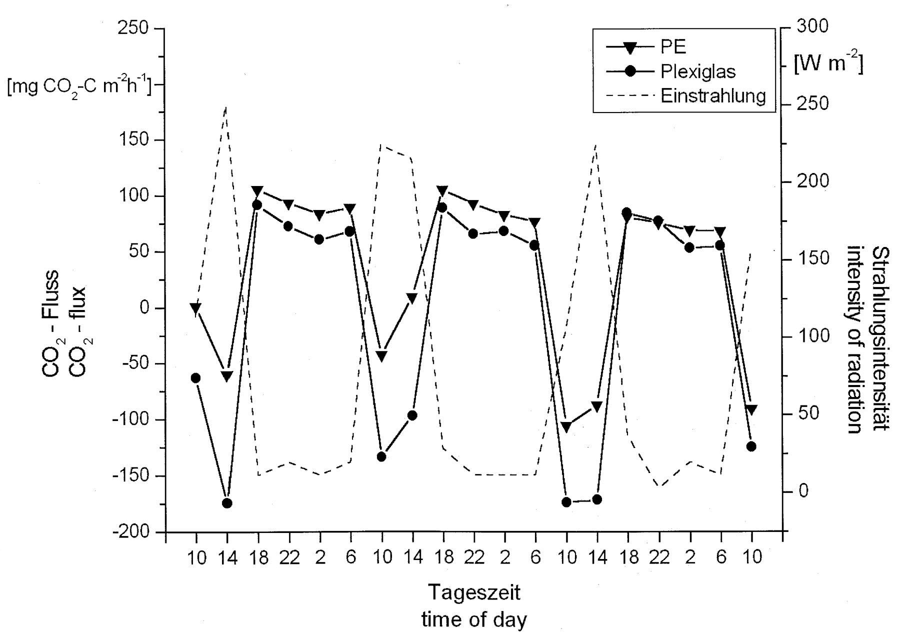

Figure 9: Run of CO_2-flux using different chamber materials, depending on radiation

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