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Sect 4 #47

AUTOMATED MONITORING OF NITROUS OXIDE AND CARBON DIOXIDE FLUX FROM FOREST SOILS

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Abstract

Gas flux determinations at the soil–atmosphere interface are of value when modeling either soil or atmospheric chemistry. We describe a system for the automated analysis of N_2O and CO_2 flux from the soil surface. Fluxes are measured by monitoring increases in N_2O and CO_2 in double-walled Plexiglas chambers at 30- and 60-min intervals after the chamber lids are closed. Opening and closing of the chamber lids, gas sampling operations, and data collection and analyses are all controlled by a personal computer. In addition to gas fluxes, air and soil temperature as well as light intensity can be monitored. Using this system, up to 12 chambers can be continuously monitored within a 300-m² area.

SOILS may act as sinks or sources for trace gases. Both input and output may be influenced by human activities such as agriculture-forestry management or industrial emissions. Mosier (1989) has evaluated the various methods by which soil fluxes are measured. Recent reviews on trace gas flux and its effects on soil and atmospheric chemistry have been published by Andrae and Schimel (1989) and by Bouwman (1990). Because there are temporal (diurnal as well as seasonal) and spatial (ground cover, exposure, and soil) variations, it is desirable to observe fluxes for a long period from a number of stations in order to develop reasonable estimates of the overall annual flux. In particular, in a study of forest ecosystems, where the soil is usually undisturbed by tilling, it is necessary for the monitoring stations not to disturb the physical, chemical, and biological integrity of the plot being monitored. This study presents a detailed description of an automated chamber system for monitoring N_2O and CO_2 flux from soil.

Materials and Methods

The principle of a static chamber system, as described by Hutchinson and Mosier (1981) and Conrad et al. (1983), was employed but with several modifications to make it more suitable to a forestry system. In particular, no incision was made into the humic layer in order to prevent root damage. Since wind effects (Matthias et al., 1980) could be expected with such a poor soil–chamber seal, the observation chamber was surrounded by a buffer zone of equal surface area. This double chamber (Fig. 1) was constructed of Plexiglas (10-mm walls with a 6 mm lid), stood 20 cm high, and covered a total area of 0.5 m². The chamber was only worked into the litter deep enough to achieve the horizontal placement required for sealing the 2-cm water-trap lid. Although the water-trap seal on the lid limits pressure differences within the chamber to 200 Pa (2 millibar), a vent was included. The chambers were normally open (lid vertical), and were only closed for 1 h in every 6 h for gas-enrichment determinations at 30- and 60-min intervals. Reed contacts, triggered by a magnet on the lid, were used as end-position motor control and as position verification.

A schematic of the gas plumbing and valving system is shown in Fig. 2. Twelve chambers were connected to a 16-port gas multiplexer valve with a 12-m length of 3-mm-i.d. Teflon tubing. These sample lines were loosely wrapped with a high-resistance wire (50 Ω/m) and encased in a polyethylene tube (9-mm i.d.) to prevent condensation of water.

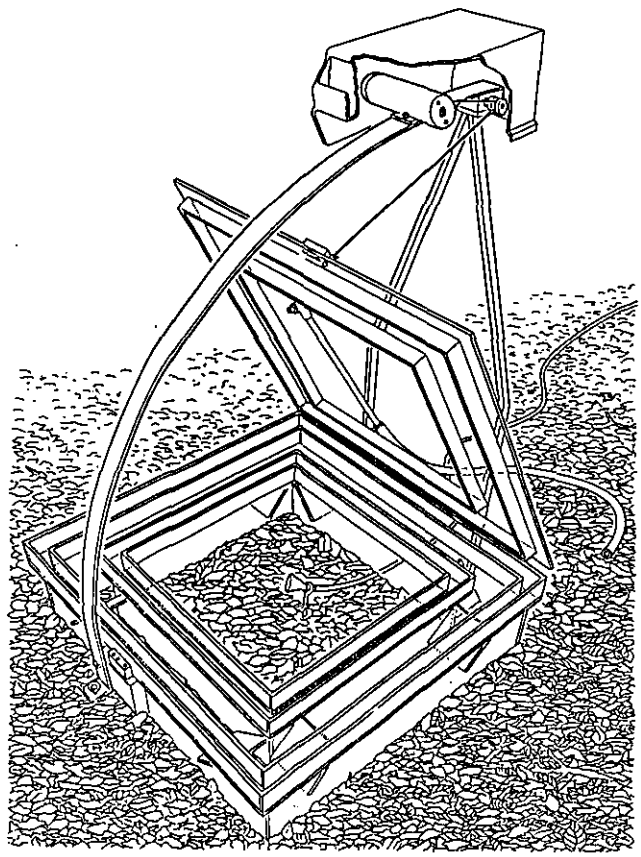

Fig. 1. Double-wall chamber with motor-driven lid.

Table 1. Sequence of timed events for a typical operation cycle of the automated soil gas chamber system.

Time	Event
s	
0	Close lid, turn on tube heater
20	Is lid closure verified? Yes: turn off lid motor No: Note ERROR! turn motor off, turn heater off, continue
1620	Evacuate (Valve V3 on)
1800	Close Valve V3
1801	Open sample valve (V1–V12), actuate valve (V1)
1860	Close sample valve (V1–V12)
1861	Open Valve V2 to equalize pressure in system
1870	Actuate sample valve (10P)
1930	Reset sample valve (10 P solid) Valve 4P to detector (solid)
1940	Open integration window
2180	Close window, valve 4P bypass detector (dotted), Integrate GC signal
3601	Repeat sampling and analysis (t = 1801 s)
3660	Open chamber, verify, turn off motor and heater

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Abbreviations: PC, personal computer; GC, gas chromatograph.

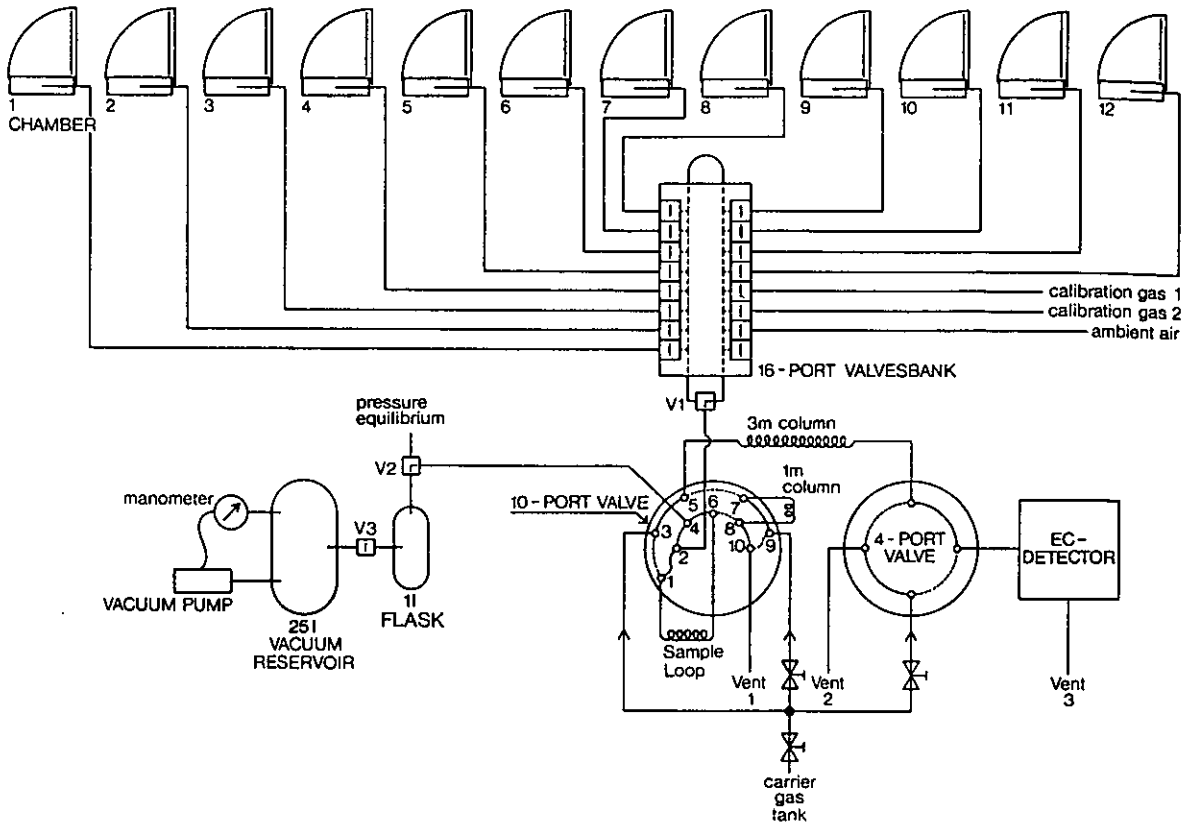

Fig. 2. Gas plumbing of the chamber sampling and gas chromatographic analysis.

The extra ports in the multiplexer valve permitted direct access to two calibration gases and a permanently positioned (5 cm above the soil surface) ambient air sample line that was used for zero-time reference. The common port of the multiplexer valve was connected to a 10-port sample–backflush valve positioned on a gas chromatograph and a 1-L sampling flask.

Air samples were analyzed using a gas chromatograph equipped with a Ni-63 electron capture detector (Carlo Erba, Hofheim, Germany). A four-port valve was used to vent interfering O_2 past the detector, as described by Mosier and Mack (1980). The 1 m precolumn and 3 m main column (both Poropak Q [Millipore, Milford, MA], 150–200 μm) were run isothermally at 0.195 MPa (80 °C, 18 mL/min) using 20.6 g/kg CH_4 in Ar as a carrier gas. Retention time of CO_2 using this system was ≈6 min.

The system was interfaced to an XT-compatible PC, which controlled four functions: (i) the operation of the chamber lids, (ii) the sample tube heaters, (iii) the multiplexer valves, and (iv) the pneumatic GC valves (Fig. 3). Interfacing was achieved using a 16-channel A/D card (no. 2814) and a 32-port I/O card (no. 2817) obtained from Data Translations (Marlborough, MA). In addition to control of sampling operations, the PC monitored the GC detector signal, the lid position of each observed chamber, light intensity, and temperature (chamber air and 5- and 0-cm soil depths).

Hardware control was achieved through software written in Turbo Pascal (Umwelt Freundliche Energieanlagen, Goettingen, Germany). One complete program cycle lasted 6 h and, during this cycle, 1-h gas flux measurements from each of the 12 chambers were performed. Light and temperature readings were collected at 5-min intervals but only recorded as hourly averages. Analysis of the signal from the GC was performed using an integration subroutine. Although peaks were immediately integrated, the original chromatogram was stored for later visual inspection.

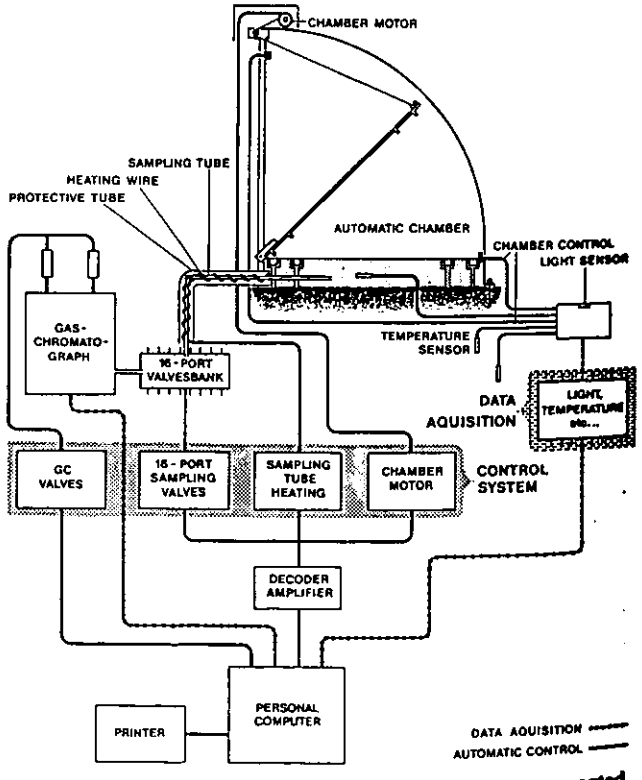

Fig. 3. Schematic diagram of the personal-computer-supported control and data acquisition.

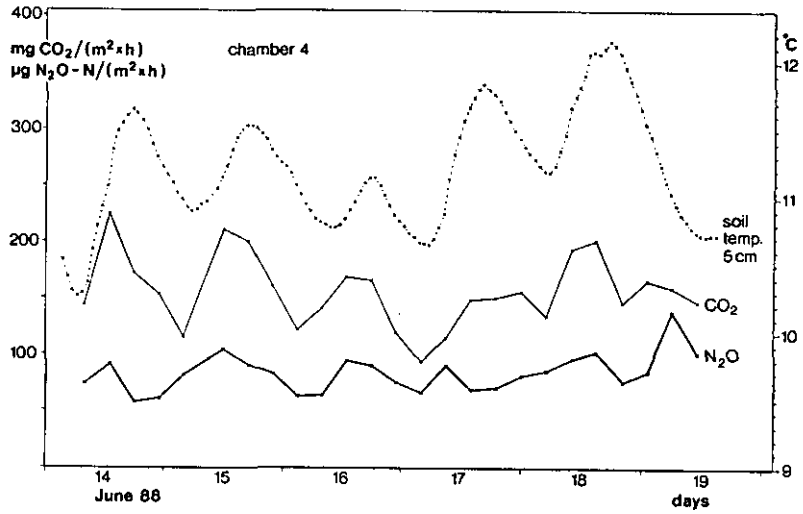

Fig. 4. Diurnal and day-to-day fluctuations of the soil temperature and the corresponding CO_2 and N_2O flux from 14 to 19 June 1988 in Chamber 4.

Operation of this system is described by examining a typical analysis cycle (Table 1). First the lid of the monitored chamber was closed. Next, the 1-L flask, the multiplexer valve, the sample lines, and the GC sample valve were evacuated (0.05–0.06 MPa) by opening Valve V3. Following this step, Valve V3 was closed and a single port on the multiplexer valve was opened. A gas sample (500–700 mL) from one of the chambers was drawn into the evacuated system, filling the 5-mL GC sample loop (10-port valve in the load position, dotted connections in Fig. 2). During this process of filling the sample loop, Valve V1 was continually switched back and forth to flush any dead volumes in the 16-port multiplexer valve. The sample port was then closed but, before sample injection could occur, the system was briefly vented to the atmosphere (Valve V2) to eliminate problems of overpressure or underpressure in the sample loop. The sample valve (10P) was then actuated, injecting the 5-mL gas sample into the GC. The sample valve was then reset and, following N_2O and CO_2 analyses, sampling was repeated.

Results and Discussion

The flux data, from an acid forest soil with a mor-type humus layer under beech (*Fagus sylvatica* L.) (Brumme and Beese, 1992), in the following diagrams were obtained using the slope of a linear fitting of the 0-, 30-, and 60-min gas concentration measurements. Because 30 to 40% of the fittings had a <0.99 coefficient of determination, and both positive and negative (convex and concave) deviations from linearity were observed, a nonlinear fitting as proposed by Hutchinson and Mosier (1981) was not applied. In general, linearity was good if the flux was large but, as can be seen in the diurnal flux pulsation in Fig. 4, loss of linearity may also result from determinations during periods of nonconstant emmisions. The amplitude of the flux increase each day varied widely, as the temperatures, but on average one can expect a 60 to 70% increase for CO_2 and a 50 to 130% increase for N_2O (related to the lowest measured flux each day). That additional factors influence the flux is demonstrated on the three chambers (Fig. 5) within a *homogeneous plot*. Although the CO_2 flux of the three replicate chambers are comparable (Fig. 5b), the N_2O results (Fig. 5a) indicate a large spatial variation within

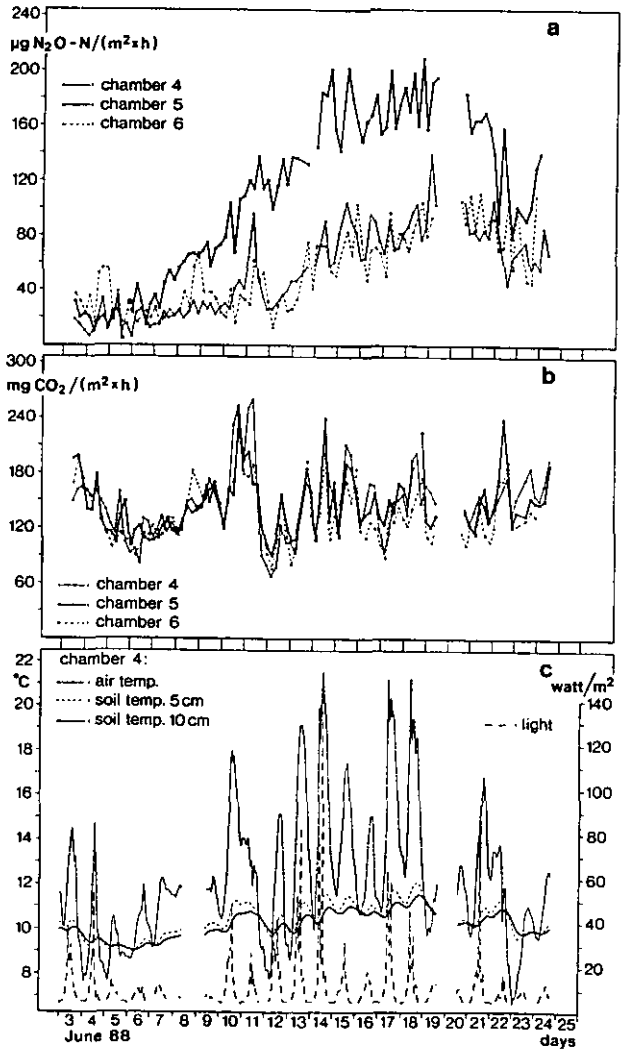

Fig. 5. Spatial and temporal variations of (a) N_2O and (b) CO_2 fluxes from three chambers within a homogeneous plot during June 1988 with the corresponding soil and air temperatures (5 and 10 cm) and the light determinations from Chamber 4.

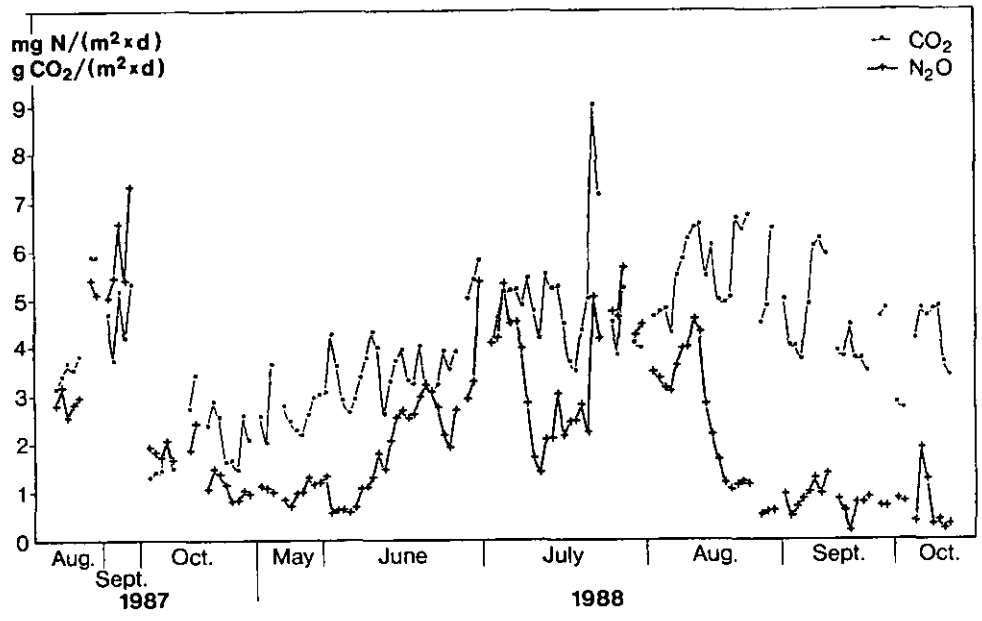

Fig. 6. Daily mean values (four flux determinations per day per chamber, three chambers per plot) of CO_2 and N_2O during 1987 and 1988.

the plot. Since long-term net output (Fig. 6) was to be estimated, daily plot flux averages were calculated (four flux determinations per day per chamber, three chambers per plot). The structural differences between CO_2 and N_2O that can be recognized here indicate that independent factors govern their production.

The large temporal variation of both CO_2 and N_2O emphasizes the necessity of methods that enable long-term yet highly time-resolved determinations of flux if one is to make even a rough estimate of total annual flux.

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