Supplementary Information for: Advancing N_2O flux chamber measurement techniques in nutrient-poor ecosystems

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1 Detailed information on measurement setup

For measuring N_2O concentrations, we used the Aeris MIRA Ultra (MU) N_2O/CO_2 high accuracy, portable online analyser. The analyser operates in the middle infrared (MIR) region (middle-infrared laser absorption spectroscopy) and can accurately measure N_2O, CO_2, and H_2O fluxes with a low power consumption (22 W). The sensitivity is <200 ppt/s for N_2O and <200 ppb/s for CO_2, with a drift of <1 ppb for N_2O, and <1 ppm for CO_2, respectively. The instruments operates well at a temperature between 5-40°C with 10 to 95% RH; however, it needs to be warmed up in at least 10°C before it can be used in temperatures below 10°C. The warming up takes around 45 min if the device has not been warmed up before; if it has, it needs <5 min to be ready again. To measure greenhouse gas concentrations in the field, the Aeris MU N_2O/CO_2 was attached to a custom made external battery box with two $LiFePO_4$ batteries (special rechargeable battery, block screw contact $LiFePO_4$ 12.8V 20Ah, Green Cell), which could be switched whilst the analyser was running. In this study, one $LiFePO_4$ 12.8V 20Ah battery lasted for the whole day of field measurements (8h- max. 12h), thus no switching between the batteries was needed. The Aeris MU N_2O/CO_2 and the necessary battery box were fitted on a L-shaped backpack (total weight ca. 13 kg). Theoretically, this system can be operated by one person only; however, we always worked with at least two people present. We used a net-like rubber foot mat in front of the collar to reduce the impact of trampling and the weight of our instruments on the palsa, and movable board walks in the bog and fen plots.

Before we started a measurement period (*i. e.*, time when chamber is closed), the tubes from the portable gas analyser were inserted into the chamber, the chamber ventilated for at least 1 minute, and gently closed on the sealing ring. In May 2023, the chamber was closed for 5- 10 min with one replicate for both light and dark measurements. In July and September 2023, the chamber was closed for 10 min without any replicate.

1.1 Chamber specs

For all field measurements, we used a custom-made transparent chamber made of acrylic glass, measuring 250 mm in height and 250 mm in diameter (Göli GmbH; Fig. S1 (a)). The chamber is equipped with handles and eight openings on the top (Fig. S1 (b)). One opening is designated for a fan connected to a power cable (, while another opening is used for a sensor that measures relative humidity (RH) and air temperature (°C) (EE08, E+E Elektronik, Germany). One of the five remaining openings has a tube linked to an external pressure transmitter that maintains a constant pressure in the chamber, similar to the

ambient pressure (61402V, RM Young). The other openings are used for inlet and outlet tubes from two portable gas analysers, allowing for additional measurement of CO_2 and CH_4 next to N_2O .
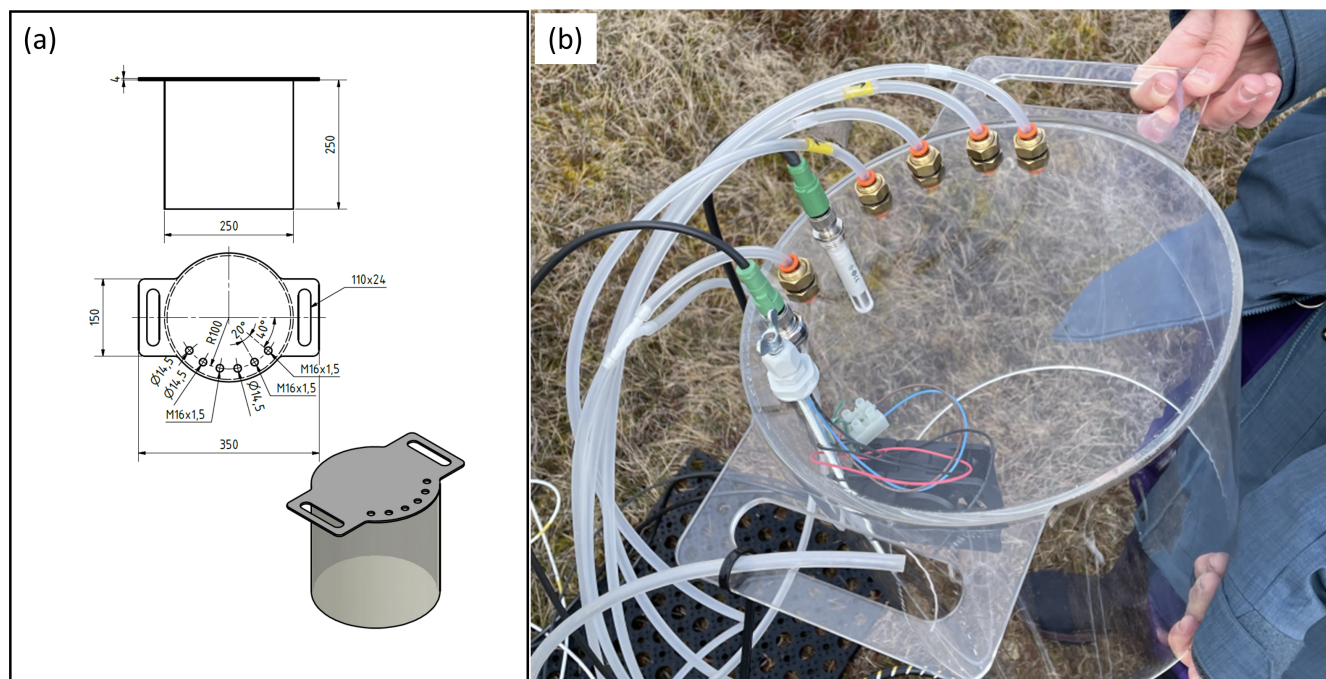
Figure S1. Technical drawing of the chamber (a) and corresponding photo of use in the field (b). Note that the drawing was originally drawn with 6 openings; 8 openings are only needed with concurrent use of two portable gas analysers. Technical drawing: Martin Hertel, Photo: Mirkka Rovamo

PVC collars, measuring 245.1 mm in inner diameter, 150 mm in height, and 4.9 mm in width, were inserted 100-130 mm into the soil to prevent atmospheric gases from entering the chamber during measurements. A custom sealing ring was placed between the collar and the chamber (Fig. S2 (a)). This ring has an inner diameter of 235 mm, an outer diameter of 265 mm, and a height of 30 mm. It consists of a metal ring covered in foam material, 50 mm thick on each side. Three nobs extended the ring by 3 mm and were wrapped in PVC tubing to keep them in place on the collar. The sealing ring sealed the chamber and the collar up to 18 m/s wind gusts; beyond this, the chamber would detach from the sealing ring if not held (Fig. S2 (b)). For dark measurements, a homemade, reflective tarp was placed over the chamber to block light.
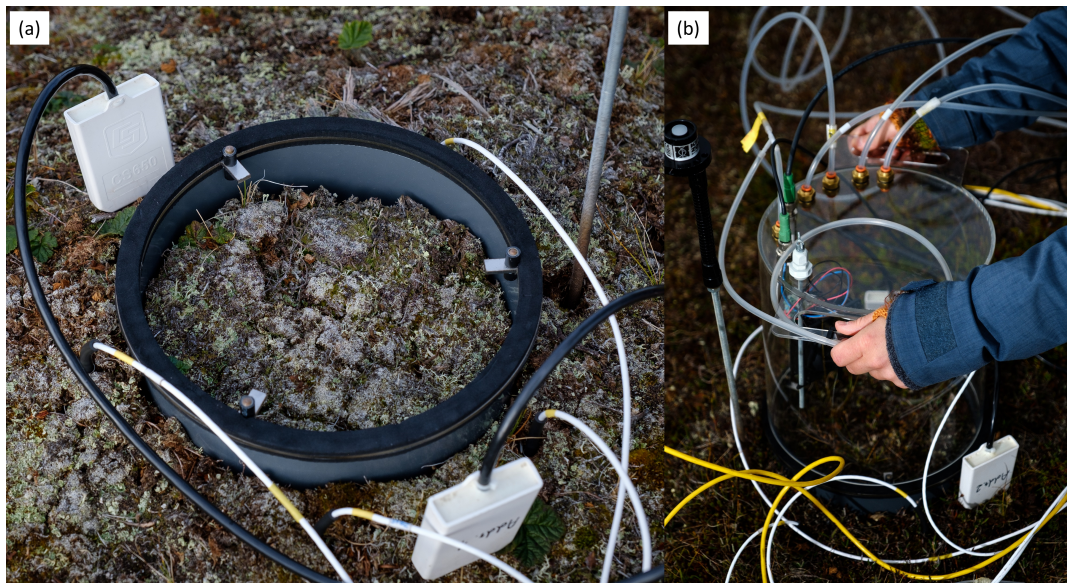
Figure S2. Photos from sealing ring in the field without (a) and with (b) chamber on top. Photos: Fabio Cian

1.2 Data logger box specs

All sensors were connected to a custom made Pelican box containing a data logger (CR1000X, Campbell Scientific), a rechargeable battery (LiFePO4 12.8 V 10 Ah, Green Cell), a Wi-Fi router (GL-AR750 Travel AC Router, GL.iNet), a GPS unit (GPS 16X-HVS, Campbell Scientific), and differential analog and digital signals for temperature, moisture, and relative humidity sensors, as well as the Aeris MU N_2O/CO_2 to the data logger (Fig. S3).
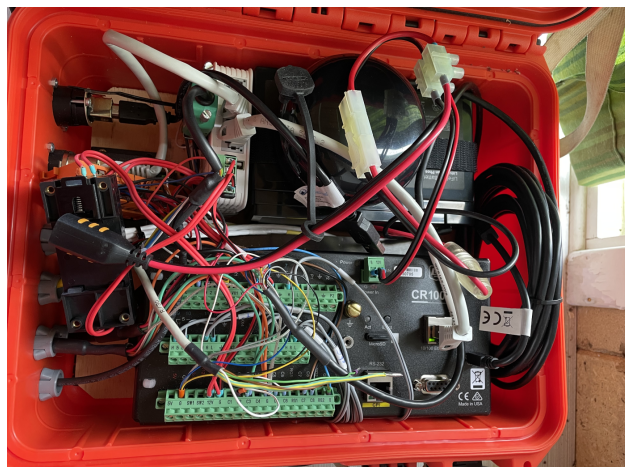
Figure S3. Inside of data logger box, with the battery underneath the GPS on the top right, the white router next to it, and the data logger with its connections on the bottom half of the Pelican box. Photo: Nathalie Ylenia Triches

40 The Aeris MU N_2O/CO_2 communicated via RS232 to the data logger (Fig. S4), and connected to a VNC interface on a SAMSUNG tablet or smartphone through the instruments' internal Wi-Fi for *in situ* quality control. Additional portable gas analysers could be connected to the data logger via Wi-Fi. The LoggerNet software on a Windows tablet was used to activate and quality-check all connections, including those for the soil temperature and moisture sensors, PAR sensor, RH/temperature sensor in the chamber, and the Aeris MU N_2O/CO_2 through the wired RS232 connection. This setup resulted in a single data

45 file containing all necessary information for analysis, instead of multiple files from individual sensors and loggers.
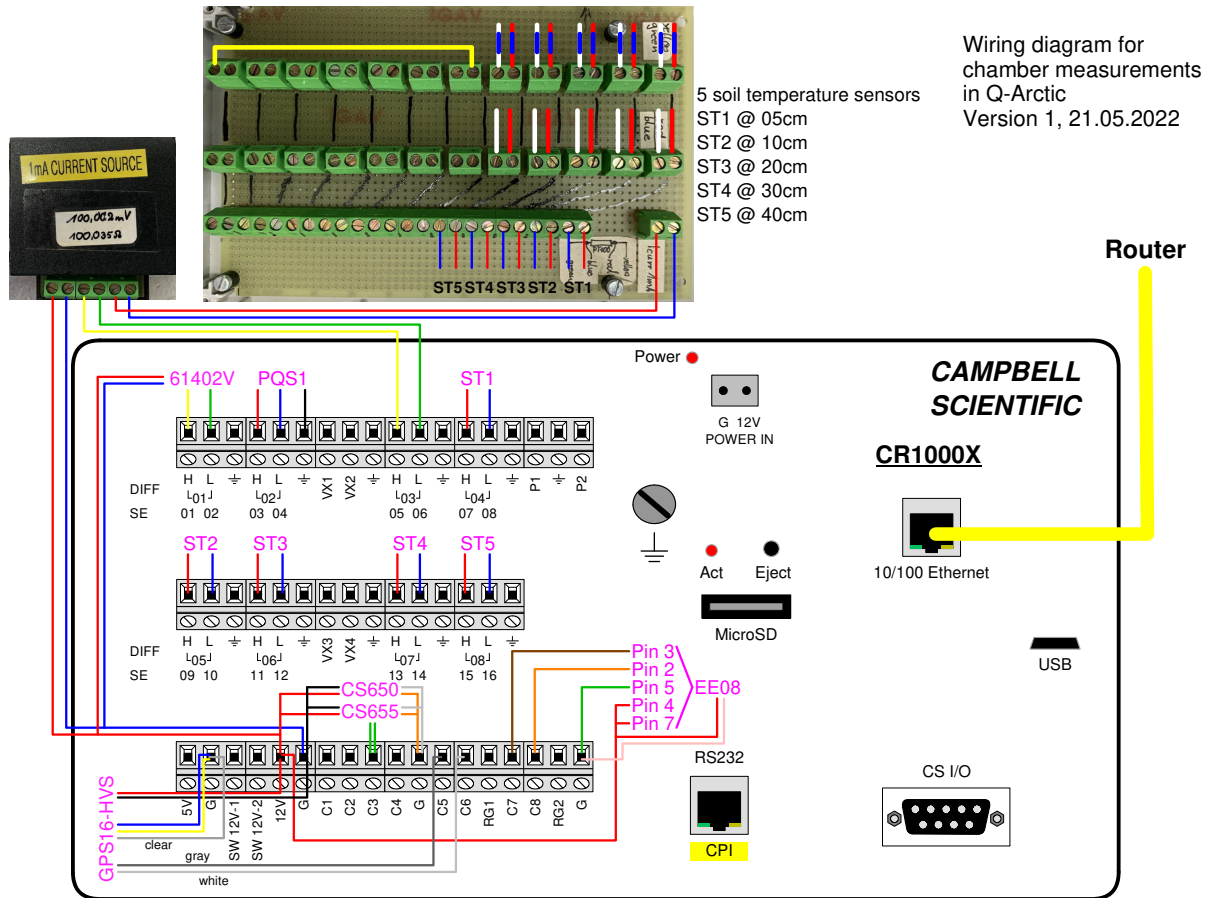
Figure S4. Wiring diagram of the data logger, with, from top left to bottom right, 61402V the pressure sensor inside the chamber, PQS1 the PAR-sensor, ST1-5 the five soil temperature sensors, GPS16-HVS the GPS, CS650/5 the volumetric water content sensors, and EE08 the temperature and relative humidity probe inside the chamber. Credit: Olaf Kolle

1.3 Information on data processing script

Due to configuration issues with the Aeris MU N_2O/CO_2 gas analyser, all data were also checked for so-called "flat lines", *i. e.*, continuous lines with concentrations less than 0.0004 ppm difference, so that were so similar that it could only be an artefact. The filter function looked for lines deviating from the median less than 0.08 ppb over a time period of 8 seconds. If a flat line was detected, it was replaced by data points created with a linear interpolation using data points from 15 seconds before and after the occurrence of flat lines. Both the original and corrected data was then plotted to visually control the concentrations. To be able to reproduce all corrections, a log file logged all necessary information concerning the filtering and corrections.

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1.4 Water vapour concentration and temperature increase during chamber closure time
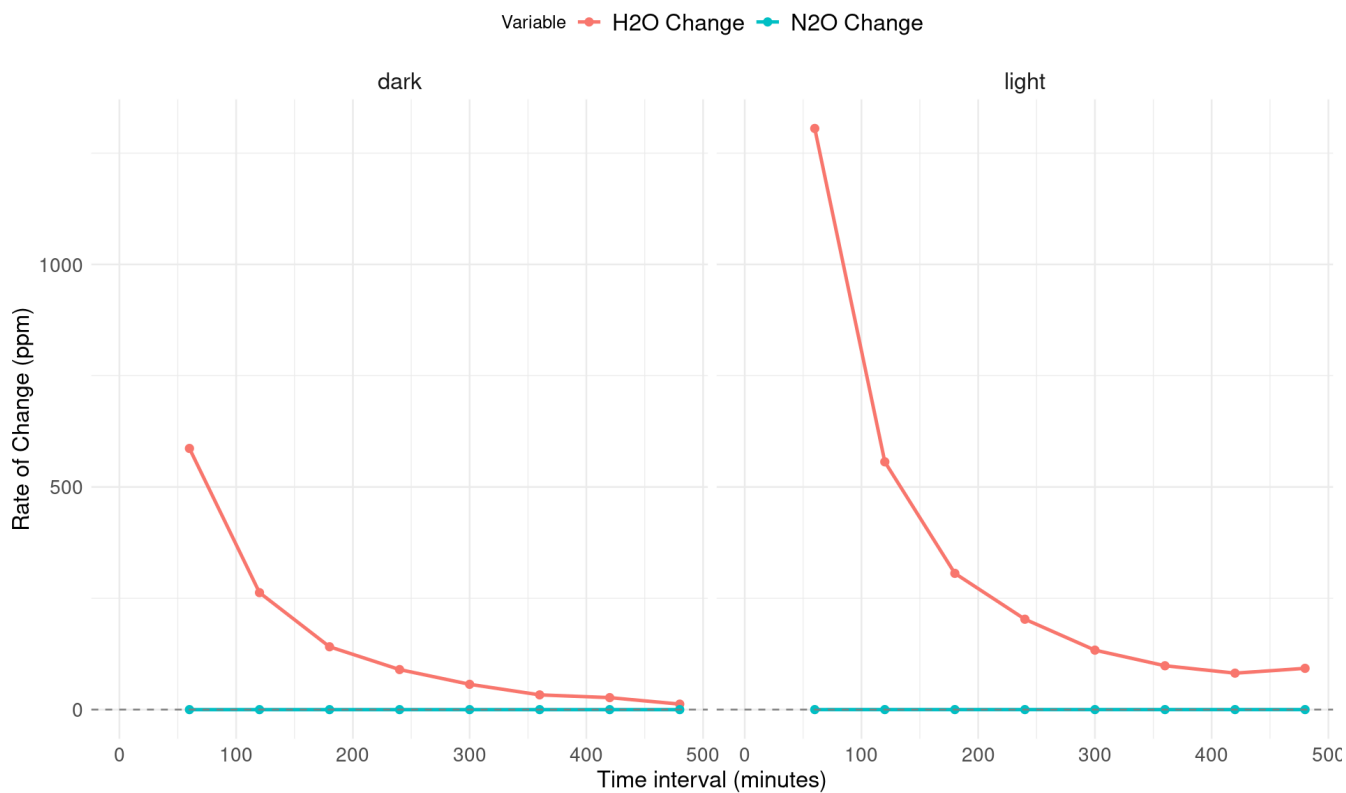
Figure S5. Rate of change on H2O and N2O concentration change during chamber closure times. The rate of change is calculated by subtracting the previous time stamp from the current, *i.e.*, rate of change = H2O concentration at (t+1) - H2O concentration at t. The left facet shows results for "dark measurements" only; the right for "light measurements". The line shows the 0 intercept.
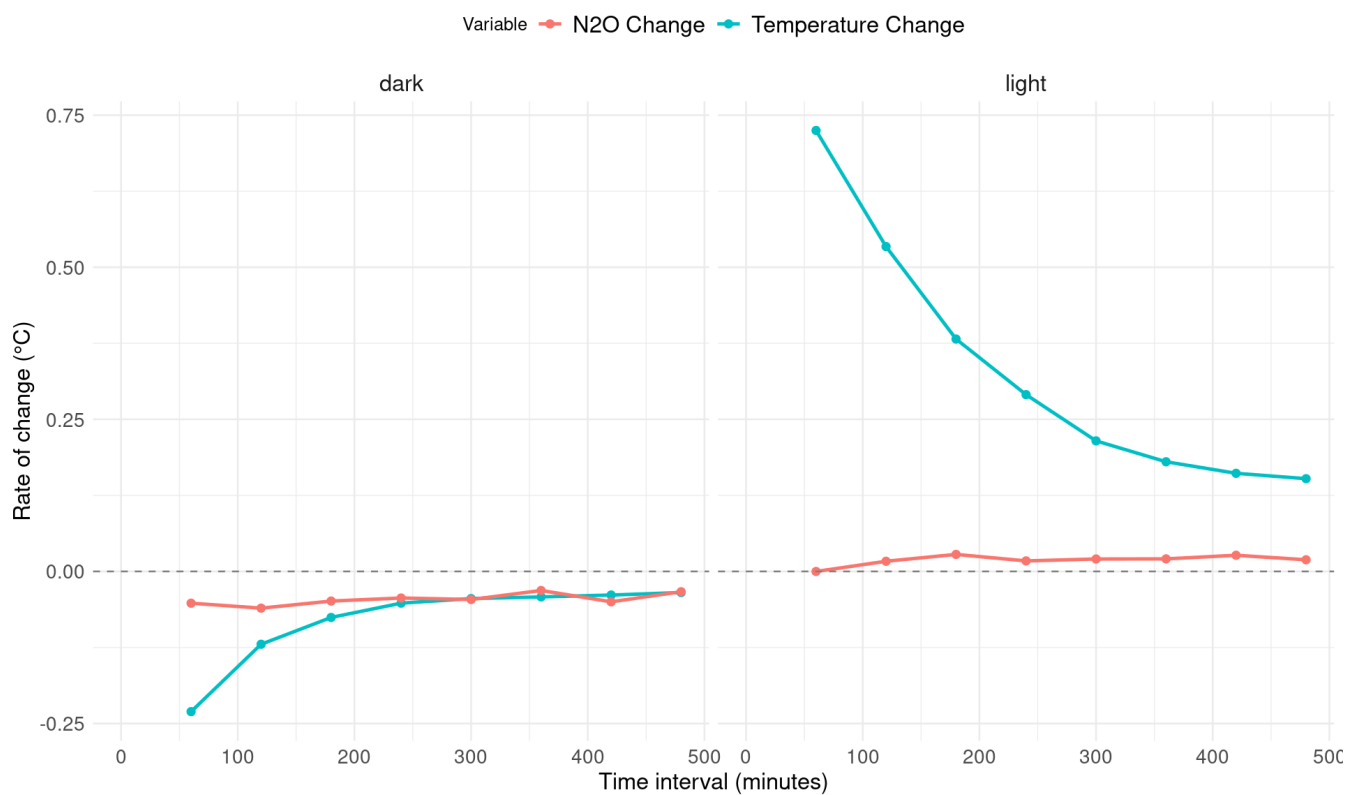
Figure S6. Rate of change on chamber temperature and N2O concentration change during chamber closure times. The rate of change is calculated by subtracting the previous time stamp from the current, *i.e.*, rate of change = chamber temperature at (t+1) - chamber temperature at t. The left facet shows results for "dark measurements" only; the right for "light measurements". The line shows the 0 intercept.