

Supplement of

**A mid-cost automated floating chamber system for high-frequency
CO₂ and CH₄ flux measurements: design, calibration, and
comparison with infrequent measurement strategies**

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Contents

Supporting Figures S1 to S17 and Supporting Tables S1 and S2.

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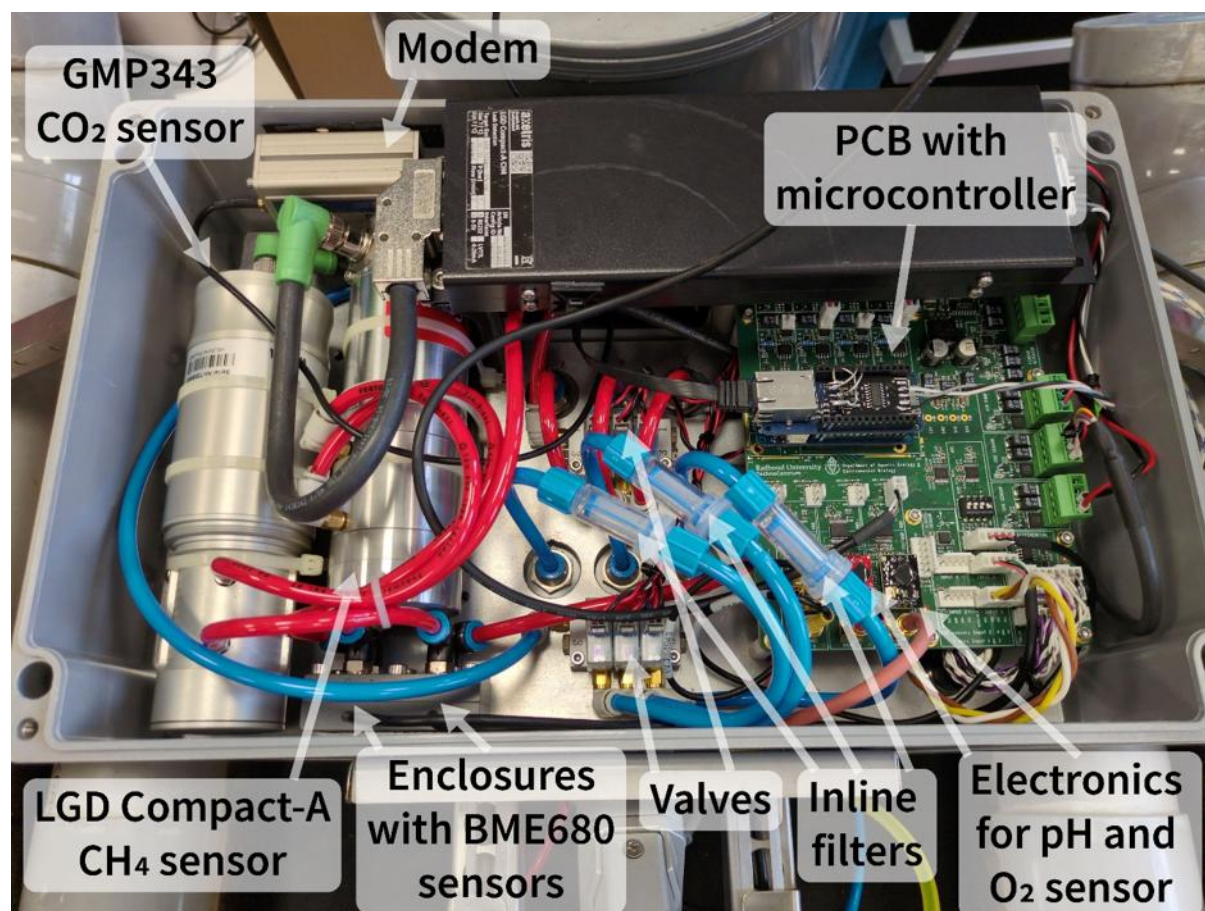


Figure S1 Photo of the box that contains the gas sensors, air pump (underneath the black electronics enclosure of the LGD Compact-A), multiplexer and electronics.



Figure S2 Visual explanation of why measurements stopped: a cow fell into the ditch on top of one of the floaters of the chamber system.



20 **Figure S3** Photo of the probe used to measure the temperature profile (10 cm intervals) in water and sediment. The probe can be connected to the chamber system to have its data log integrated with that of the other sensors.

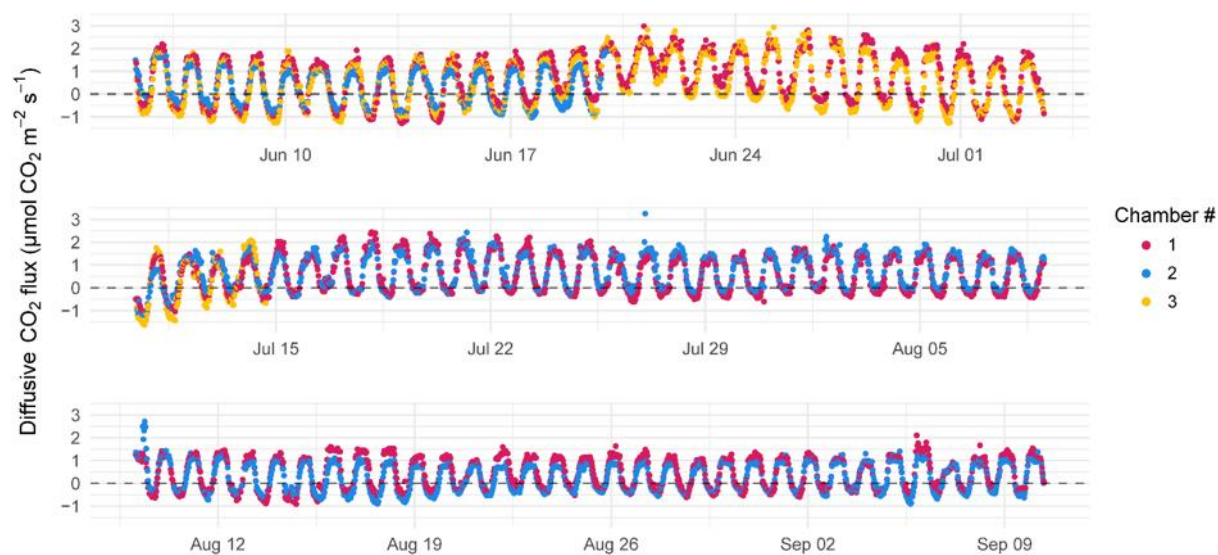


Figure S4 Temporal variation in individual diffusive CO₂ fluxes. Colours represent different chambers. The dashed horizontal line represents zero emissions.

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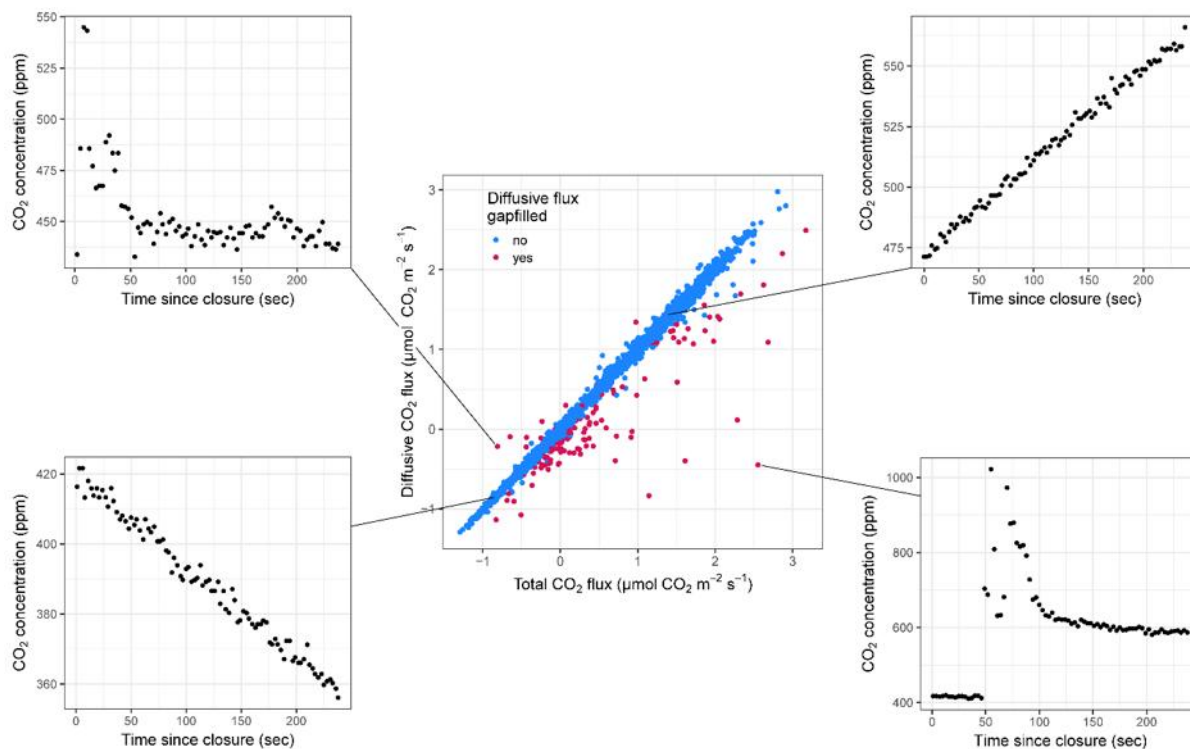


Figure S5 Total CO₂ fluxes plotted against diffusive CO₂ fluxes for chamber 1. Red dots of the centre figure denote diffusive fluxes that were gap-filled via linear interpolation, since the concentration change over time of these chamber measurements did not allow for

application of linear regression. Panels show examples of cases where the diffusive CO₂ flux $\approx$ the total CO₂ flux as well as an example of the total CO₂ flux being larger than diffusive CO₂ flux and vice versa. The ‘time since closure’ on the x-axis of the plots is corrected for the gas transit time (i.e., deadband) of the chamber measurement. See Sect. 2.4 for how total and diffusive fluxes were calculated. Note that total CO₂ fluxes in this figure were not filtered by the SD of the first and last six concentration measurements as was done for total CH₄ fluxes (see Sect. 2.6 for details). The most extreme cases where estimated diffusive CO₂ fluxes exceed the total CO₂ flux (e.g., the example in the upper left panel) can be excluded by setting a maximum allowed SD for the first and last six concentration measurements to limit including biased total flux estimates (as explained in Sect. 2.6).



Figure S6 Pressure measured within the plumbing system by the sensor located near the inlet of the CO₂ sensor (Fig. 2). The colours represent each of the different flux chambers.

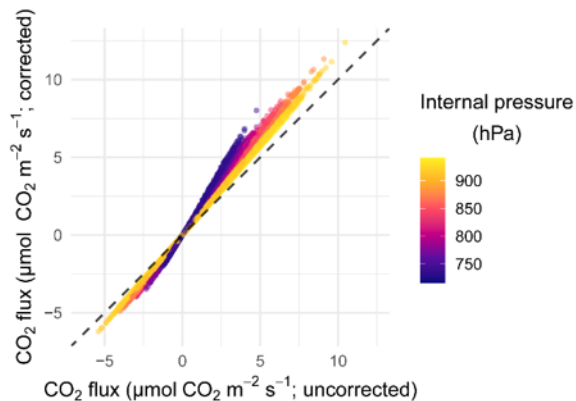


Figure S7 Water-atmosphere CO₂ fluxes not corrected for effects of pressure on CO₂ concentrations reported by the sensor (x-axis) against pressure-corrected water-atmosphere CO₂ fluxes (y-axis). The dots are coloured by the pressure measured by a BME680 sensor in the gas flow loop near the inlet of the CO₂ analyser (Fig. 2). The presented data were corrected for the effects of water vapour on the reported CO₂ concentrations.

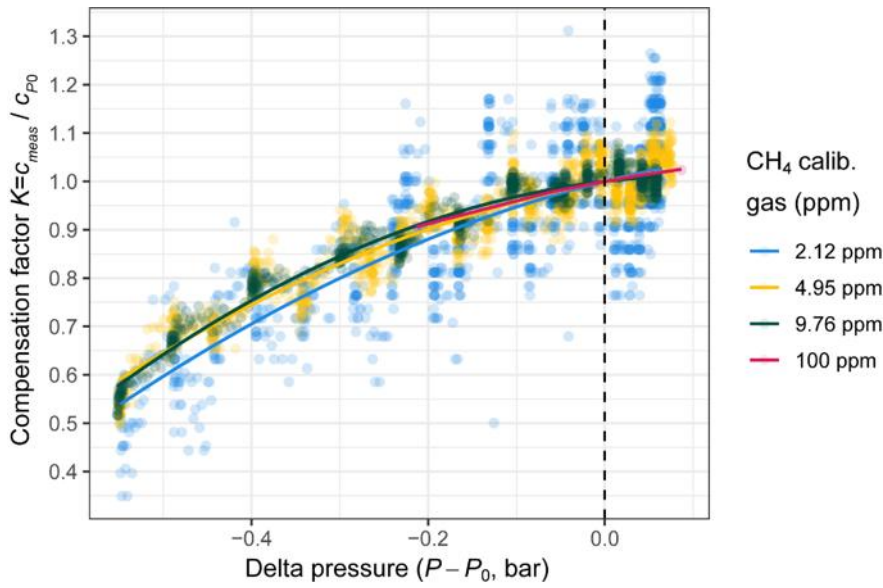


Figure S8 Compensation factor K as a function of delta pressure for calibration gases with four different CH_4 concentrations. Concentration and pressure data for the fit of the 100 ppm CH_4 data were provided by Axetris, the other data is generated during this study using the procedure described in Sect. 2.2. The dots represent the values of K for individual measurements (Eq. (1) of the main text), and the lines show the fitted relationships based on Eq. (2) in the main text.

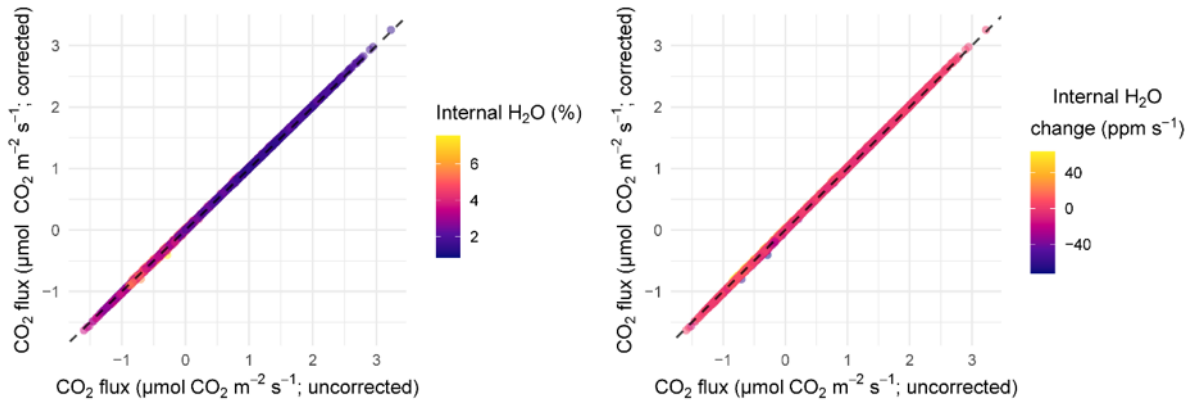


Figure S9 Water-atmosphere CO_2 fluxes not corrected for the effects of water vapour on measured CO_2 concentrations (x-axis) against water vapour-corrected water-atmosphere CO_2 fluxes (y-axis). The dots are coloured by the mean H_2O percentage (left) or change in H_2O percentage (right) that was calculated (as described in Sect. 2.3) from measurements of a BME680 sensor located near the outlet of the CO_2 sensor (Fig. 2). The CO_2 concentrations used for the fluxes were compensated for pressure variations.

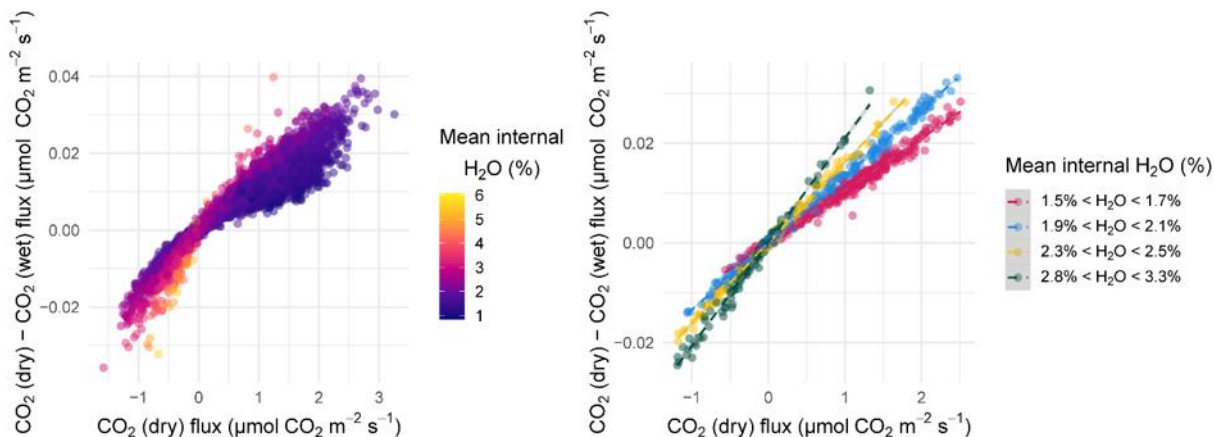


Figure S10. Water vapour-corrected ('dry') water-atmosphere CO₂ fluxes (x-axis) against the difference between the water vapour-corrected CO₂ fluxes and CO₂ fluxes not corrected for the effects of water vapour ('wet' flux) on the CO₂ concentrations reported by the sensor; y-axis). The dots are coloured based on the mean H₂O % (left, using a continuous colour scale) and categorically using a subset of the data to better illustrate the effect of the water vapour concentration. The CO₂ concentrations used for the fluxes were compensated for pressure variations. To largely isolate the effect of the mean H₂O content from the effect of the rate of change in H₂O during the chamber measurement (see Fig. S11 for the latter), we only included data where the rate of change in gas H₂O during the chamber measurement was < 1 ppm s⁻¹.

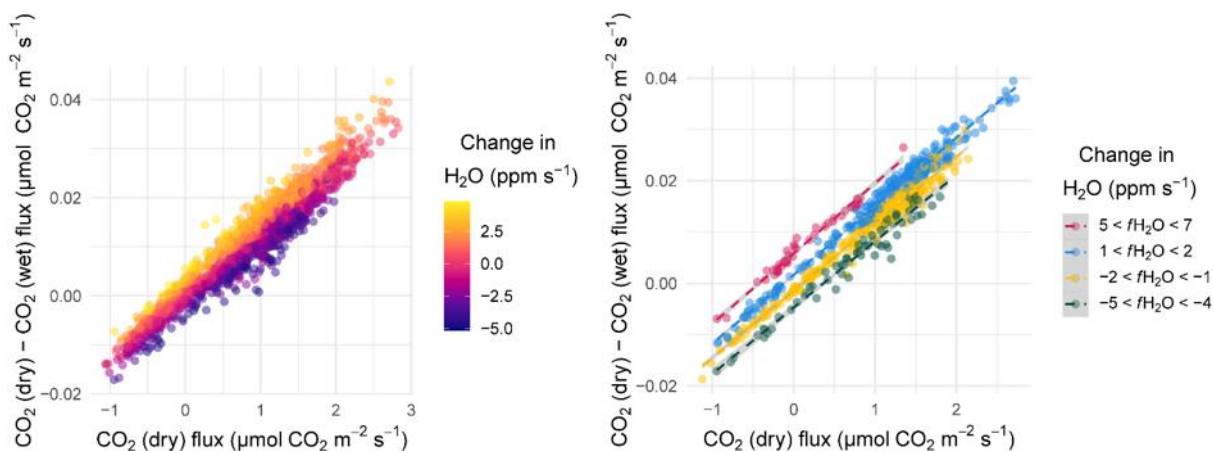
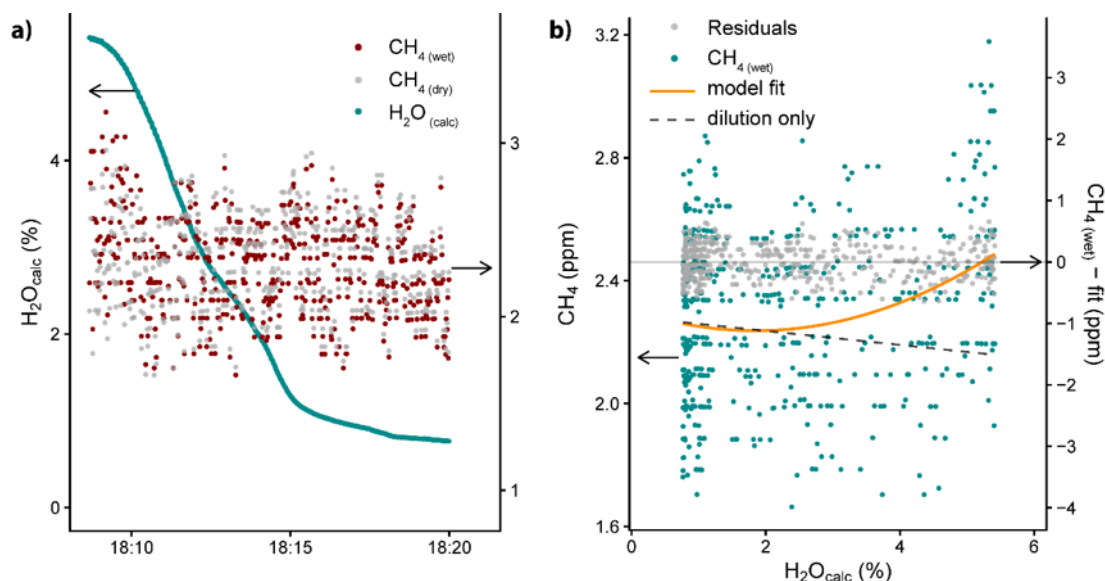


Figure S11 Water vapour-corrected ('dry') diffusive water-atmosphere CO₂ fluxes (x-axis) against the difference between the water vapour-corrected CO₂ fluxes and CO₂ fluxes not corrected for the effects of water vapour ('wet flux') on the CO₂ concentrations reported by the sensor (y-axis). The dots are coloured according to the rate of change in H₂O. Both graphs are based on a subset of the data—excluding the 2.5 % largest rates of change in H₂O of each tail—for clarity. The CO₂ concentrations used for the fluxes were compensated for pressure variations. To largely isolate the effect of the rate of change in H₂O from the effect of the mean H₂O (see Fig. S10 for the latter), we only included data in this figure where mean H₂O was between 1.75 % and 2.25 %.



75 **Figure S12 a)** Changes in water vapour uncorrected reported CH₄ mole fractions (CH₄(wet); red dots) and H₂O fractions (H₂O_{calc}, cyan line; calculated based on measurements of relative humidity, temperature, and pressure [see Sect. 2.3 for details]) over time during the water vapour interference experiment. The grey dots denote the water vapour-corrected CH₄ concentrations (CH₄(dry)) based on the parameters obtained from the model fit (Eq. (6)). **b)** Water vapour-uncorrected reported CH₄ mole fractions (CH₄(wet), cyan dots) against H₂O fractions. The orange line represents the regression line (i.e., the fitted correction function). The grey dots denote the residuals (right y-axis). The black dashed line demonstrates the bias caused when only accounting for the dilution effect of H₂O.

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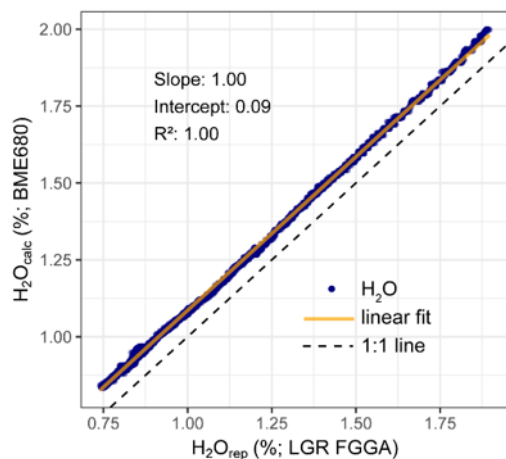


Figure S13 Water vapour concentrations calculated from measurements of relative humidity, temperature, and pressure by a BME680 sensor (H₂O_{calc}) located inside our plumbing system near the outlet of the CO₂ analyser (see Sect. 2.3 for details) compared with water vapour concentrations reported (H₂O_{rep}) by a fast greenhouse gas analyser (FGGA-24r-EP, Los Gatos Research) that received the gas exiting our system. Droplets of ultrapure water (Milli-Q, Millipore) were injected into a hydrophobic filter placed between the tubing that

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delivered dry calibration gas to the system, similar to the approach described by Rella et al. (2013). The evaporation of these droplets created the range of water vapour shown in the graph. The blue dots denote individual observations. A linear regression of the measured data (orange line) yields a coefficient of determination (R^2) and slope of 1, but a slight zero offset (intercept) of 0.09 from the dashed 1:1 line. The latter could be a true difference but may also be explained by a slight reduction in water vapour concentration of the sample (e.g. adsorption to the tubing) before it was measured by the FGGA.

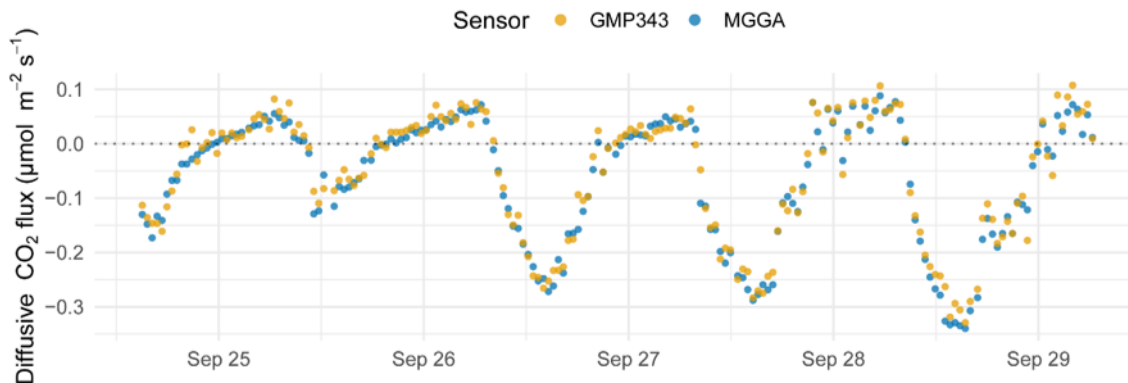


Figure S14 Diffusive CO_2 fluxes calculated based on the (pressure- and water vapour-corrected) CO_2 concentrations of the GMP343 CO_2 sensor against fluxes calculated using (water vapour-corrected) CO_2 concentrations measured by a Microportable Greenhouse Gas Analyser (MGGA; ABB Inc.) that was temporarily added in a parallel plumbing configuration on the tube of one of the three automated chambers. Chamber measurements of the automated floating chamber system were conducted in an experimental ditch at the university campus in late September 2025. The dotted, horizontal line denotes a flux of zero.

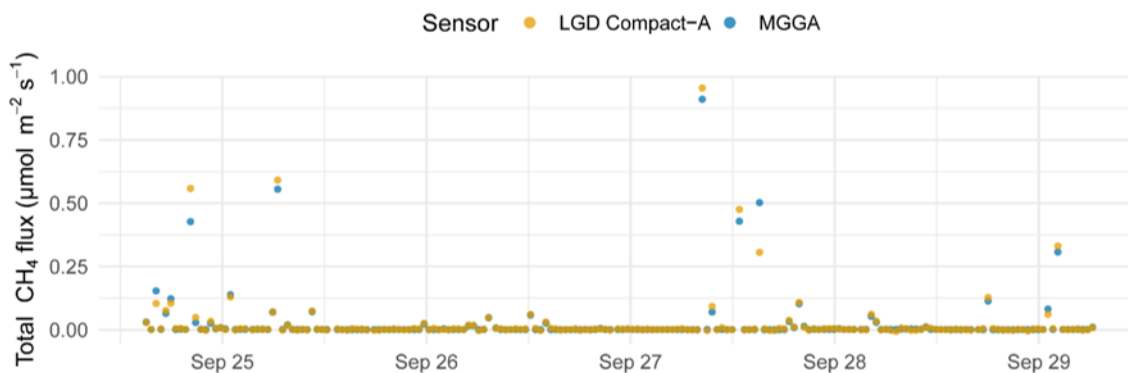


Figure S15 Total CH_4 fluxes calculated based on the (pressure- and water vapour-corrected) CH_4 concentrations of the LGD Compact-A CH_4 sensor against fluxes calculated using (water vapour-corrected) CH_4 concentrations measured by a Microportable Greenhouse Gas Analyser (MGGA; ABB Inc.) that was temporarily added in a parallel plumbing configuration on the tube of one of the three automated chambers. Chamber measurements of the automated floating chamber system were conducted in an experimental ditch at the university campus in late September 2025.

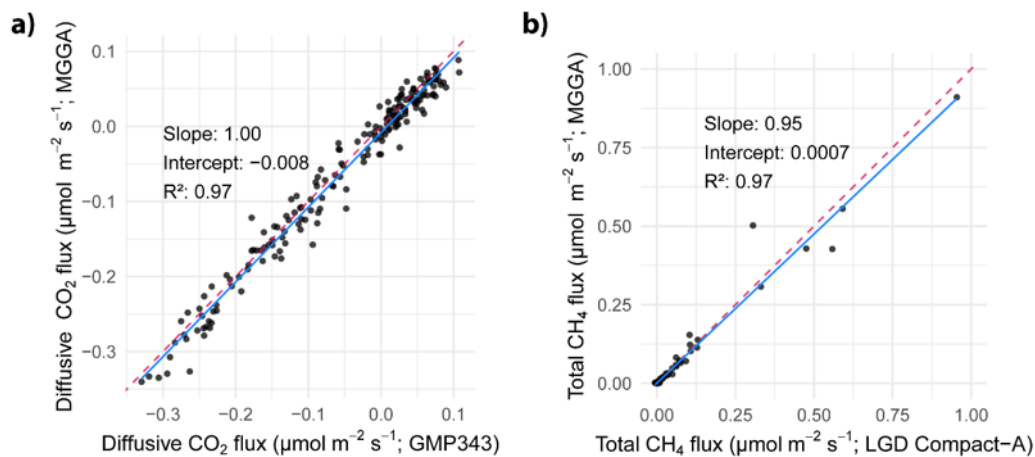


Figure S16 a) A linear regression of the diffusive CO_2 and b) total CH_4 flux estimates shown in Fig. S14 & Fig. S15, respectively. The straight blue line represents the fitted linear relationship. A 1:1 relationship is shown as a red, dashed line for comparison. Statistics of the linear regression are shown in the text box. See the captions of Fig. S14 & Fig. S15 for further details.

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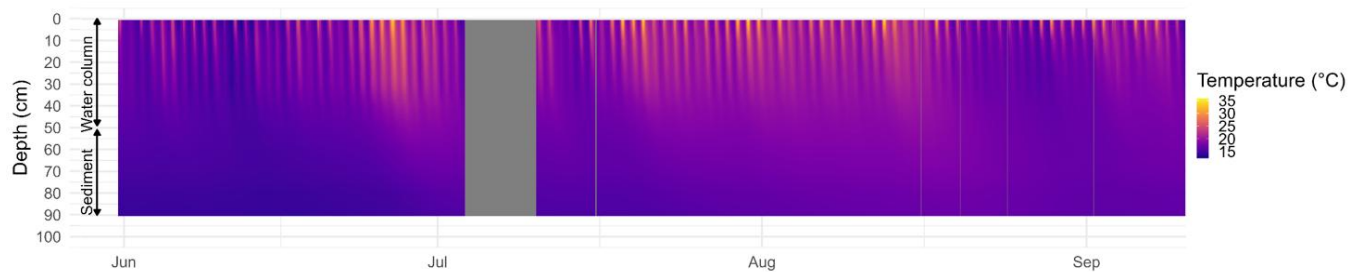


Figure S17. Timeseries of a vertical temperature profile based on measurements of the temperature probe that is part of the automated floating chamber system.

Table S1. Parameter values and their standard error (SE) resulting from fitting Equation 2 on the data presented in Fig. 5 and Fig. S8 for CO₂ and CH₄, respectively. Note that for CH₄, there was no evidence for an interaction between the reported concentration and pressure. Hence, data of the 5 and 10 ppm CH₄ gas were pooled for fitting Eq. (2).

Sensor	Gas species	c_{P0} (ppm)	A (± SE)	B (± SE)
GMP343	CO ₂	187.9507	0.502862 (8.249e-3)	1.093646 (3.350e-3)
GMP343	CO ₂	593.9218	0.310901 (3.199e-3)	1.316245 (1.343e-3)
GMP343	CO ₂	984.0261	0.424559 (3.824e-3)	1.474555 (1.685e-3)
LGD Compact-A	CH ₄	- (universal)	-0.8273686 (2.605e-2)	0.2988605 (1.118e-2)

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Table S2. Parameter values and their standard error (SE) resulting from fitting Equation 6 on the data presented in Fig. 6 and Figure S12 for CO₂ and CH₄, respectively.

Sensor	Gas species	a (± SE)	b (± SE)
GMP343	CO ₂	-6.181158e-03 (5.734e-04)	-2.485906e-04 (9.810e-05)
LGD Compact-A	CH ₄	-3.1434e-2 (1.5541e-2)	8.513e-3 (2.598e-3)

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References

Rella, C. W., Chen, H., Andrews, A. E., Filges, A., Gerbig, C., Hatakka, J., Karion, A., Miles, N. L., Richardson, S. J., and Steinbacher, M.: High accuracy measurements of dry mole fractions of carbon dioxide and methane in humid air, *Atmospheric Measurement Techniques*, 6, 837-860, <https://doi.org/10.5194/amt-6-837-2013>, 2013.