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OPAQUE CLOSED CHAMBERS BIAS METHANE MEASUREMENTS OF CONVECTIVE PLANTS

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SUMMARY

Commonly, closed chamber measurements for methane and nitrous oxide emission estimation are carried out with opaque chambers. However, some plants possess an internal convective gas transport which quickly responds to changes in irradiation. We compare methane fluxes derived from transparent versus opaque chambers on *Carex*-, *Phragmites*-, and *Typha*-dominated stands. Transparent chamber fluxes almost doubled opaque chamber fluxes at the *Phragmites* stand. For *Carex* and *Typha*, transparent and opaque chamber fluxes did not differ significantly. Thus, opaque chambers bias the outcome of methane measurements depending on dominant vegetation. We recommend the use of transparent chambers when determining emissions of convective plants or extrapolating fluxes to larger scales.

KEY WORDS: PAR, fen, Phragmites, Typha, Carex

INTRODUCTION

Peatlands substantially influence atmospheric concentrations of the three major greenhouse gases (GHGs) carbon dioxide, methane and nitrous oxide (Parish *et al.*, 2008). Due to the growing recognition of the importance of peatlands as GHG sources and sinks, reliable estimates of emissions from a wide range of peatland types will be needed in the future.

Commonly, micrometeorological methods (such as eddy covariance) and closed-chamber measurements are used to assess GHG emissions. Closed-chamber systems are often preferred (e.g. due to lower monetary investments) but reach their limits in ecosystems such as temperate minerotrophic fens where large emergent wetland plants frequently dominate the vegetation cover. The same plants have been found to transmit a large fraction of the methane released to the atmosphere from the sediment (Kim *et al.*, 1998; Ding *et al.*, 2005). Frequently, opaque chambers are used for estimations of methane and nitrous oxide emissions (e.g. Tauchnitz *et al.*, 2008; Hendriks *et al.*, 2010). However, some emergent wetland plants possess an internal convective gas transport which main use is the transmission of oxygen to the anaerobic root zone. Simultaneously it channels methane emissions from the sediment to the atmosphere. This transport is known to quickly respond to changes in photosynthetically active radiation (PAR) (Dacey, 1981; Armstrong *et al.*, 1992). Methane emissions transmitted by such plants have also been shown to immediately decrease with reduced light incidence in the field (van der Nat and Middelburg, 2000). Still, due to the long closing times the use of transparent chambers for methane measurements is problematic, resulting in an effective heating of the chamber headspace and by this biasing emissions.

In this study we tried to quantify the bias caused by the exclusion of light on methane emission estimates of characteristic vegetation of temperate minerotrophic fens, as well as to evaluate the practicability of transparent chamber measurements in the field. We tested the following two hypotheses: (1) Abiotic properties of a transparent chamber headspace can be maintained constant during a closure time of 40 minutes (with the help of a portable cooling system), and (2) estimates of methane emissions on plants with internal convective transport differ when using opaque and transparent chambers.

MATERIAL AND METHODS

Field measurements were conducted in the Trebel valley in the federal state of Mecklenburg-Western Pomerania, Germany (54° 06‘ N; 12° 44‘ E). The investigation area is dominated by a large minerotrophic percolation mire. As most peatlands in this region, it was subjected to heavy drainage and intensive agricultural use since the 1960’s. In 1997 a 3000 ha large area including the investigation area was rewetted. Since then hunting constituted the only land use. Peat thickness in the investigation area varies from 4 to 6 m.

Carex acuta L.-, *Phragmites australis* (CAV.) TRIN. ex STEUD.-, and *Typha latifolia* L.-dominated plant stands were sampled to compare plants with convective and diffusive transport. In each plant stand two collars were installed two weeks prior to the first measurement in August 2011. We used flexible closed chambers with an enclosed volume of approximately 0.6 m^3. In both chambers (transparent and opaque) headspace air was circulated with a ventilator installed inside an external pipe. In the transparent chamber the external pipe led through an enclosing Styrofoam box which contained cold water together with blocks of ice, directly cooling the walls of the pipe. To increase contact surface area, a copper tube helix was additionally installed inside the pipe, through which the surrounding ice-cold water was circulated with an electrical pump. To account for the high temporal and spatial variability of emissions we established the following measuring procedure: Starting at 06:00 a.m., the transparent and the opaque chamber were simultaneously set up on the two neighboring collars of one plant stand. At the end of the closure time and following a 20 minute lag time chambers were switched and the measurement repeated. We continued in this alternating manner until 02:00 pm, when the last measurement was started. This resulted in a total of eight measurements on each spot during one day. Closure time was 40 minutes during each measurement for both chamber types. During this time 5 gas samples were taken using evacuated glass flasks (60 ml). Gas samples were analyzed for methane concentrations by a gas chromatograph (Perkin Elmer Auto System) with a Flame Ionization Detector (FID) within 24 hours. The precision of analysis ranged at about 50 ppb.

We estimated gas fluxes using the *flux* package (Jurasinski and Koebsch, 2011) for the statistical software R. Only fluxes with concentrations outside the precision range of the gas chromatograph and a R^2 of at least 0.8 were included in further analyses. All statistical analyses were performed using R 2.12.2 (R Development Core Team, 2011). To assess the impact of the chamber on CH_4 fluxes we calculated linear mixed effect models for diffusive (*Carex*) and convective plants (*Phragmites* and *Typha*) with chamber kind as fixed effect and spot, air temperature, and relative humidity as random effects. For model estimation and pvalue calculation we used the packages *lme4* (Bates, 2011) and l*anguageR* (Baayen, 2011). Level of significance was 0.05; all averages are given with ± 1 SE.

RESULTS

Mean PAR values during measurements were 417 ± 52 µmol m^{-2} s^{-1} in *Carex* stands, 415 ± 36 µmol m^{-2} s^{-1} in *Phragmites* stands, but only 219 ± 36 µmol m^{-2} s^{-1} in *Typha* stands. During the measurements, air temperature increased on average 1.1 ± 0.2 °C in the opaque chamber, and 1.2 ± 0.3 °C in the transparent chamber (Fig. 1). On average, Relative humidity remained relatively stable in the opaque chamber (0.2 ± 0.3%) while it slightly decreased in the transparent chamber (-2.8 ± 0.9%).

In the *Phragmites* stand the mean flux of the opaque chamber was 5.6 ± 0.9 mg CH_4 m^{-2} h^{-1} while it was 10.0 ± 1.1 mg CH_4 m^{-2} h^{-1} of the transparent chamber. In contrast, in *Carex* both chamber kinds on average did not yield different estimated fluxes (9.0 ± 1.0 mg CH_4 m^{-2} h^{-1} by the opaque chamber, and 9.0 ± 1.5 mg CH_4 m^{-2} h^{-1} by the transparent chamber). In *Typha* fluxes varied slightly when estimated with different chamber types (opaque: 11.7 ± 1.0 mg CH_4 m^{-2} h^{-1}; transparent: 13.3 ± 1.4 mg CH_4 m^{-2} h^{-1}). Overall, the chamber effect was significant (p = 0.01) in convective plant stands (*Phragmites* and *Typha*). In contrast, chamber kind did not have a significant effect on estimated fluxes of the diffusive plant stand (*Carex*).

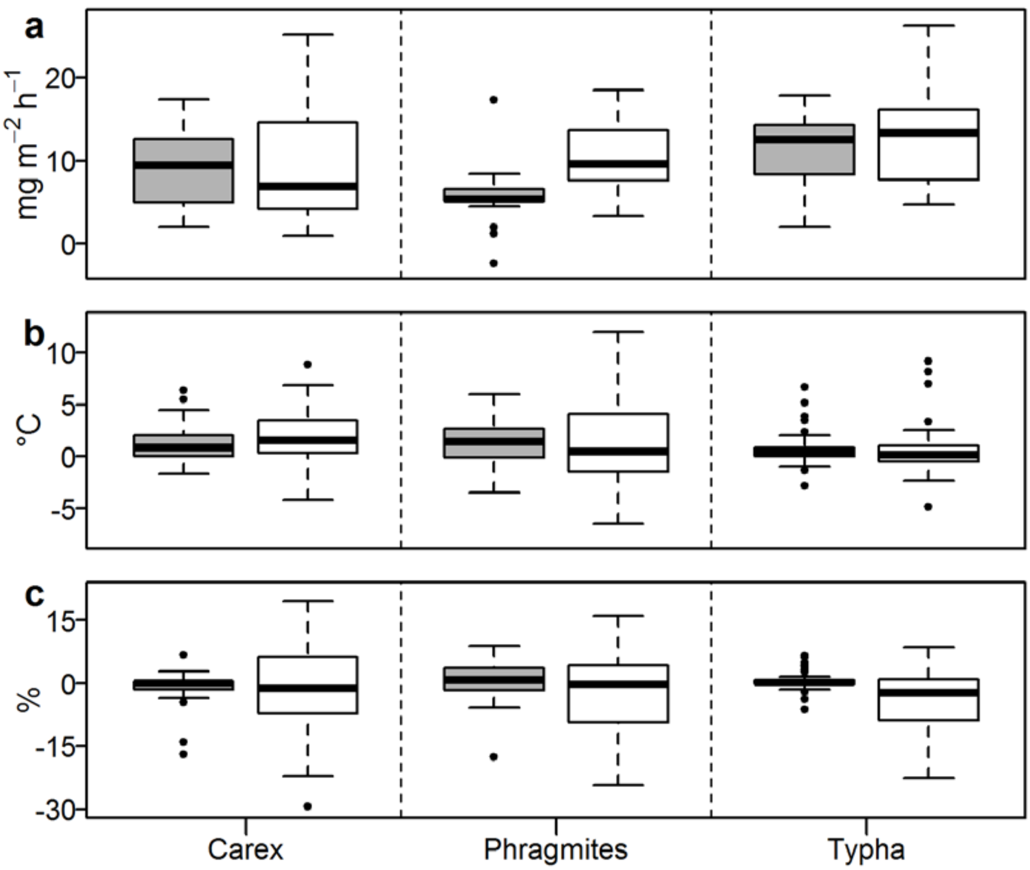

Figure 1: Methane fluxes (a), changes in air temperature (b), and changes in relative humidity (c) during measurements on three vegetation stands. Grey boxes show opaque chamber, white boxes transparent chamber values. Whiskers mark the data lying within the 1.5 interquartile range. n = 24.

DISCUSSION

Our first hypothesis could be approved with reservations. During the measurements, air temperature and relative humidity displayed only slight changes, but with higher variability in the transparent than in the opaque chamber. This indicates the need for fine adjustments of the cooling system when manipulating air temperature and relative humidity. The system used in this study in some cases reacted too slowly to maintain a constant environment. Convective transport in plants is known to quickly react not only to changes in PAR, but also air temperature and corresponding relative humidity since it is in most cases humidity-induced (Armstrong and Armstrong, 1991; Bendix *et al.*, 1994). Therefore, conditions inside the chamber need to be controlled very carefully to neither increase nor decrease convective flow.

We are able to show in this study that methane emissions are lowered when using opaque chambers on convective plants (hypothesis 2). In *Phragmites australis*, fluxes were almost doubled when using the transparent chamber. This species has been found to possess internal pressurization which resulting convective air flow drives methane emissions (Chanton *et al.*, 2002). PAR incidence plays a major role in regulating internal pressures and corresponding methane emissions in *Phragmites* (van der Nat *et al.*, 1998; Arkebauer *et al.*, 2001). We therefore hypothesize that emissions measured by the transparent chamber describe the actual emissions more accurately than those measured by the opaque chamber. For further validation of this hypothesis, future studies should compare long-term measurements of both chamber kinds with eddy covariance data, or directly measure internal pressures and methane concentrations in the aerenchyma during chamber measurements. Whiting and Chanton (1996) found a reduction in methane emission rates on *Typha* when the (transparent) chambers of their study were darkened. The lack of a pronounced difference in our study might indicate that internal pressures in *Typha* do not react as sensitively as pressures in *Phragmites* to changes in PAR. Alternatively, the cloudy conditions and the resulting low PAR during measurements on *Typha* diminished the chamber effect.

Taking into account the results obtained by this study we strongly recommend the use of transparent chambers for methane measurements on convective plants. This holds especially true if the data obtained are used to extrapolate to large temporal or spatial scales. If transparent chamber measurement should constitute the standard for methane emission analysis in the future, sensitive portable cooling systems need to be developed.

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REFERENCES

Arkebauer T.J., Chanton J.P., Verma S.B. and Kim J. (2001). Field measurements of internal pressurization in Phragmites australis (Poaceae) and implications for regulation of methane emissions in a midlatitude prairie wetland. *American Journal of Botany* **88**, 653–658.

Armstrong J. and Armstrong W. (1991). A convective through-flow of gases in Phragmites australis (Cav.) Trin. ex Steud. *Aquatic Botany* **39**, 75–88.

Armstrong J., Armstrong W. and Beckett P.M. (1992). Phragmites australis: Venturi- and humidity-induced pressure flows enhance rhizome aeration and rhizosphere oxidation. *New Phytologist* **120**, 197–207.

Baayen R.H. (2011). *languageR: Data sets and functions with "Analyzing Linguistic Data: A practical introduction to statistics"*. R package.

Bates D. (2011). *lme4: Linear mixed-effects models using S4 classes*. R package.

Bendix M., Tornbjerg T. and Brix H. (1994). Internal gas transport in Typha latifolia L. and Typha angustifolia L. 1. Humidity-induced pressurization and convective throughflow. *Aquatic Botany* **49**, 75–89.

Chanton J.P., Arkebauer T.J., Harden H.S. and Verma S.B. (2002). Diel variations in lacunal CH4 and CO2 concentration and d13C in Phragmites australis. *Biogeochemistry* **59**, 287–301.

Dacey J.W.H. (1981). Pressurized ventilation in the yellow waterlily. *Ecology* **62**, 1137–1147.

Ding W., Cai Z. and Tsuruta H. (2005). Plant species effects on methane emissions from freshwater marshes. *Atmospheric Environment* **39**, 3199–3207.

Hendriks D.M.D., van Huissteden J. and Dolman A.J. (2010). Multi-technique assessment of spatial and temporal variability of methane fluxes in a peat meadow. *Agricultural and Forest Meteorology* **150**, 757–774.

Jurasinski G. and Koebsch F. (2011). *flux: Flux rate calculation from dynamic closed chamber measurements*. R package.

Kim J., Verma S.B., Billesbach D.P. and Clement R.J. (1998). Diel variation in methane emission from a midlatitude prairie wetland: Significance of convective throughflow in Phragmites australis. *Journal of Geophysical Research* **103**, 28029–28039.

Parish F., Sirin A., Charman D., Joosten H., Minayeva T., Silvius M. and Stringer L. (eds.) (2008). *Assessment on Peatlands, Biodiversity and Climate Change: Main Report, Kuala Lumpur, Malaysia and Wageningen, The Netherlands*. Global Environment Centre and Wetlands International.

R Development Core Team (2011). *R: A language and environment for statistical computing, Vienna, Austria*. R Foundation for Statistical Computing.

Tauchnitz N., Brumme R., Bernsdorf S. and Meissner R. (2008). Nitrous oxide and methane fluxes of a pristine slope mire in the German National Park Harz Mountains. *Plant and Soil* **303**, 131–138.

van der Nat F.-J.W.A., Middelburg J.J., van Meteren D. and Wielemakers A. (1998). Diel methane emission patterns from Scirpus lacustris and Phragmites australis. *Biogeochemistry* **41**, 1–22.

Whiting G.J. and Chanton J.P. (1996). Control of the diurnal pattern of methane emission from emergent aquatic macrophytes by gas transport mechanisms. *Aquatic Botany* **54**, 237–253.