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Effect of moderate warming and soil humidity gradient on net carbon exchange of a *Sphagnum* peatland.



Pierrick Priault¹, Caroline Plain¹, Christophe Guimbaud², Grégory Bernard¹, André Clerc³, Valéry Catoire², Alexandre Butler⁴ and Daniel Epron¹

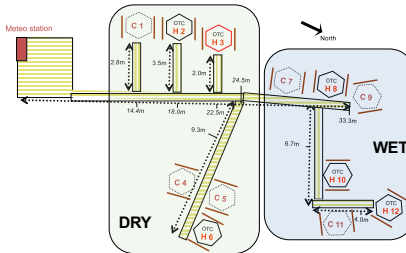
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INTRODUCTION

The PEATWARM project¹ supported by the French ANR aims to evaluate the impact of a moderate temperature rise and of substrate moisture on the pool of peat organic matter and hence the long-term carbon sequestration potential of peatland ecosystems using the standard International Tundra Experiment protocol in a natural and undisturbed ombrotrophic french bog in Frasne (Doubs, see map below).

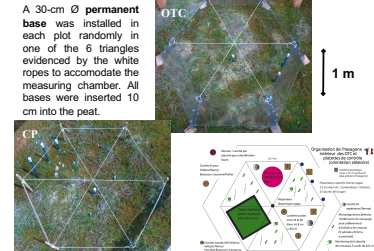


In this context, *in situ* CH₄ and CO₂ exchange measurements were set up and CO₂ isotopic discrimination of respiratory fluxes characterized in relation to temperature treatment (OTC) and soil humidity gradient (Wet and Dry sites) along the Frasne bog as described below.



Scheme of the research station of Frasne

Open Top Chamber (OTC) and a Control Plot (CP).

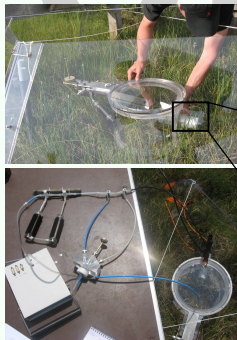


Plot organisation scheme

FIELD EXPERIMENTAL DESIGN

CO₂ samplings and measurements

- Four permanent CO₂ sample transparent chambers will be established in 2010 on *Sphagnum* surfaces. These chambers will be placed to deal with the different treatments (OTC vs Control and Dry vs Wet conditions) and will be weekly moved from one plot to another.
- Peat and *Sphagnum* samples collection and Keeling plots measurements will be performed periodically from March to November.



Automatization
High-time-resolved measurements of overall CO₂ fluxes during 5 min chamber closed, every 30 min.



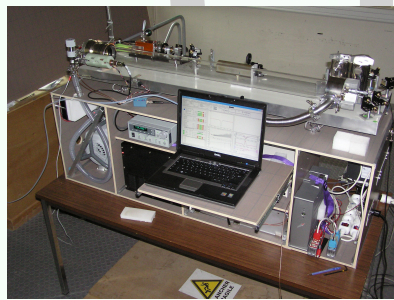
permanent T°C, air H, PAR, CO₂ follow

Gas collection for isotopic analysis

CH₄ measurements

SPiRiT (SPectrometre Infra-Rouge *In situ* Troposphérique) is a portable infrared laser absorption spectrometer designed and built at the LPC2E (CNRS Orléans), using a patented long path optical cell and a tunable Quantum Cascade Laser² (see picture below). The instrument and the process to derive trace gas concentrations for CH₄ in the atmosphere are described in full details^{3,4} and some points are presented below.

The vibration line at 1270.78503 cm⁻¹ was used for the detection of CH₄². Precision to the concentrations for CH₄ is better than 0.2%³, with absolute uncertainties less than 3% for a response time of 1.5 sec⁴.



The optical cell of SPiRiT is connected to a closed chamber for flux measurements of CH₄ (see below). Chambers methods are known to be more appropriate than micrometeorological methods in the cases of (i) spatial variation of the emissions as it is the case for CH₄ in peatlands and (ii) a detailed process-oriented study of flux emissions needs to be achieved as it is the purpose in most of our field investigations.

In closed chambers, the flux is obtained from the rate of accumulation of the considered gas during several minutes. The flux detection limit is 3.61 g C-CH₄ hect⁻¹ day⁻¹ (1.5*10⁻² mg C-CH₄ m⁻² h⁻¹). Precision for fluxes are better than 1% above 10 times flux detection limits. The global uncertainty on fluxes are better than 5%, mainly due to the additional uncertainty on the mean height of the chamber.

SPiRiT in field situation



RESULTS

First field measurement campaigns were performed this summer on June 25th (CO₂ + CH₄) and September 7-8th (CO₂)

1a Representative bases randomly included in plots described above, hosting gas measuring chamber. Pictures were taken on September 10th.



Dry Site (C4) Wet Site (H12)

2 CO₂ and CH₄ overall net exchanges. Net ecosystem-atmosphere CO₂ fluxes were estimated in the dark and under full light (NEE_{dark} and NEE_{light} respectively). CH₄ fluxes were estimated as described above. Results are expressed in μmoles.m⁻².s⁻¹ and presented ± Std Error.

	Dry		Wet	
	CP(C4)	OTC(H12)	CP(C11)	OTC(H12)
*NEE _{dark}	3.75	2.21	1.80	1.82
NEE _{light}	1.95 ± 0.50	1.51 ± 1.20	-0.63 ± 0.2	-0.61 ± 0.06
CH ₄ efflux	0.11 ± 0.01	0.09 ± 0.01	0.08 ± 0.02	0.08 ± 0.005

*NEE_{dark} was measured only once on four plots, one of each conditions (C4, H6, C11, H12), while the others parameters were repeated on the whole plots. Positive NEE values mean a net CO₂ flux from the ecosystem to the atmosphere, while negative NEE values mean a net CO₂ assimilation by the peatland cover.

⇒ No significant « OTC effect » on gas fluxes apart for dark respiration that was lower in the dry OTC characterized by a lower substrate temperature during this night.

⇒ Both CO₂ and CH₄ fluxes were affected by the humidity gradient with both higher C effluxes under dry conditions (see Hypothesis and future prospects for discussion).

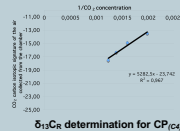
1b 40-cm-peat cores collected in June 2008 close to dry (left) and wet (right) OTC and control plots.



DRY WET

3 Isotopic analysis. The Keeling plots method is used to determine the carbon isotopic composition of ecosystem respired CO₂ (δ₁₃C_R, in ‰).

δ ₁₃ C _R	Dry		Wet	
	CP(C4)	OTC(H12)	CP(C11)	OTC(H12)
	-23.74	-24.42	-24.13	-23.58



⇒ No clear differences between treatments arise from these isotopic data.

In addition to repeat these measurements during the whole season, this approach aiming to better understand the processes and the relative plants/peat contributions involved in the ecosystem respiration will be combined with controlled conditions experimentations (See Future prospects).

HYPOTHESIS AND FUTURE PROSPECTS

No clear effect of OTC on CO₂ and CH₄ emissions

CH₄ and CO₂ fluxes (both in terms of fluxes intensity and of net exchanges) are known to be highly sensitive to substrate temperature. But after one year, no consistent effect of OTC was observed on both air and substrate temperatures.

CO₂ and CH₄ emissions are affected by substrate water status, being exacerbated on dry plots compared to wet ones.

CH₄ emissions from peatlands could be related to the relative cover of *Sphagnum* mosses and vascular plants. Indeed, vascular plants (Cottongrass, sedges, ...) are more present on dry plots (see pictures above) and it has been suggested that their root exudates activate methanogenesis bacteria by injecting labile carbon source (Gogo *et al.*, pers. comm.). In addition, their root system could also act as a diffusive channel for gas from peat to the atmosphere.

Differences observed on CO₂ net exchanges may be related more to diffusive effects than to changes in plant communities. Night and day peat CO₂ effluxes may be slowed by water in wet plots, increasing for these sites the contribution of the aerial parts for the overall ecosystem net CO₂ exchanges.

Estimating a carbon balance of a sunny summer day in Frasne bog

Data were integrated at the day scale considering a 15h light/9h night photoperiod and assuming similar and constant day/night CH₄ effluxes and constant night and day CO₂ exchanges. If both wet and dry sites appeared as sources of carbon, marked differences were obtained in terms of (i) their source intensity and (ii) the relative contribution of the methane in the overall C balance.

gC/day/m ²	Dry		Wet	
	CP(C4)	OTC(H12)	CP(C11)	OTC(H12)
	0.60	0.86	0.17	0.16

⇒ The characterization under controlled conditions of individual and global responses of gas exchange and isotopic discrimination of plant and peat samples to temperature and substrate moisture using an incubator coupled with a tunable diode laser spectrometer (TDLS) is in progress.

⇒ In addition to the continuous CO₂ exchange measurements, two CH₄-SPiRiT campaigns are planned for 2010 to explore the temporal variability of these emissions.

⇒ These data will be involved in the preparation of a peatland-based carbon biogeochemical model including the response to temperature and moisture disturbances of the different above-ground compartments.

REFERENCES

- 1 PEATWARM: this european project examines to what extent climatic warming can modify the functioning of peatlands in temperate regions and thus to deteriorate their carbon sink function investigating the effects on (1) vegetation, (2) the balance of above- and belowground C fluxes (especially by the isotopic signature of respired CO₂), (3) microbial diversity and activity in *Sphagnum* mosses and peat, and (4) the dynamics of labile and recalcitrant OM of the peat substrate. Main coordinator: Fatima Laggoun-Defarge (ISTO - Orléans, France).
- 2 Robert C. (2007) Simple, stable, and compact multiple-reflection optical cell for very long optical paths. *Applied Optics* 46(22), 5408-5418.
- 3 Joly L. *et al.* (2008) Development of a spectrometer using a cw DFB quantum cascade laser operating at room temperature for the simultaneous analysis of N₂O and CH₄ in the Earth's atmosphere. *Applied Optics*, 47(9), 1206-1214.
- 4 Guimbaud C. *et al.* First field measurements of N₂O and CH₄ fluxes at the soil-atmosphere interface using the new infra-red spectrometer SPiRiT, in preparation to *Environmental Sciences and Technology*.
- 5 Rothman, L.S. *et al.* (2005) The HITRAN 2004 molecular spectroscopic database. *JQSRT* 96, 139-204.