

Spring and Fall Conditions Explain the Interannual Variability in Carbon Exchange in a Boreal Peatland



Marie-Claude Bonneville and Ian B. Strachan
 Department of Natural Resource Sciences, McGill University, 21 111, Lakeshore Road, Ste-Anne-De-Bellevue, QC, Canada, H9Z 3V9
marie-claude.bonneville@mcgill.ca; ian.strachan@mcgill.ca



1. Background

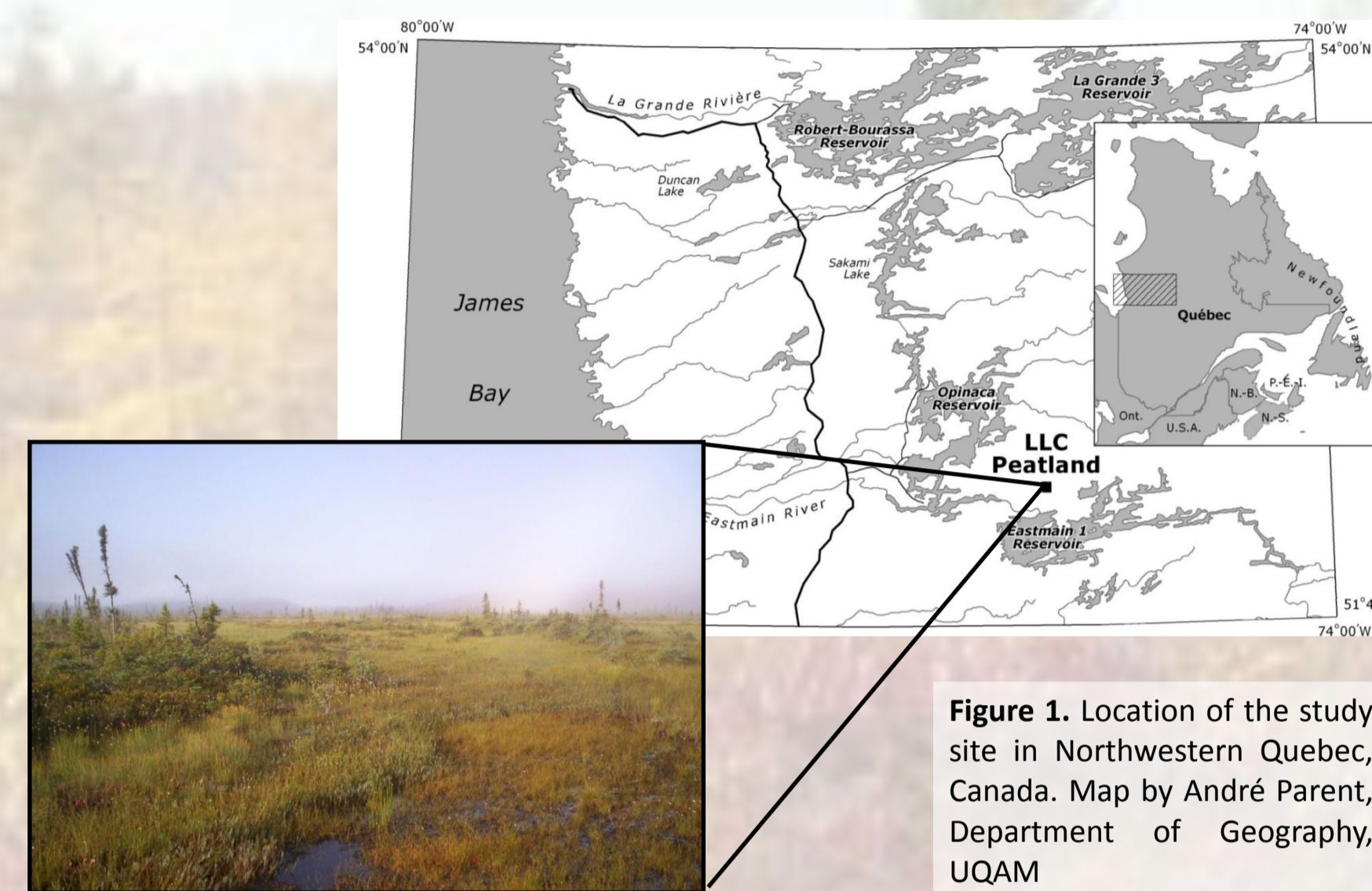
- Peatlands cover large areas of the boreal and subarctic regions globally and represent a substantial carbon (C) store (276 to 455 Pg C) (Gorham, 1991)
- The prevailing cool and wet conditions of the peat slow organic matter decomposition and plant respiration rates, leading to greater photosynthetic CO₂ uptake than C release
- Especially over longer time scales, peatlands are important components of the global C cycle, and consequently of the global climate
- On shorter time scales, the processes controlling net CO₂ exchange are very sensitive to climatic and environmental conditions (Roulet, 2000); slight changes can have a significant effect CO₂ emission and absorption
- There is a need to better understand the mechanisms governing the response of peatland ecosystems to climate and environmental variability. This will improve our understanding of the potential consequences of changing ecosystem C budgets within a changing climate

2. Research Objectives

- 1) Compare the May-to-October net CO₂ fluxes and budgets for two consecutive years over diurnal and seasonal time scales;
- 2) Investigate the major environmental controls of the CO₂ flux components (NEE, ER, and GEP), with an emphasis on the effects of temperature, water table depth and light availability;
- 3) Demonstrate the influence of spring and fall environmental conditions on interannual variability in NEE

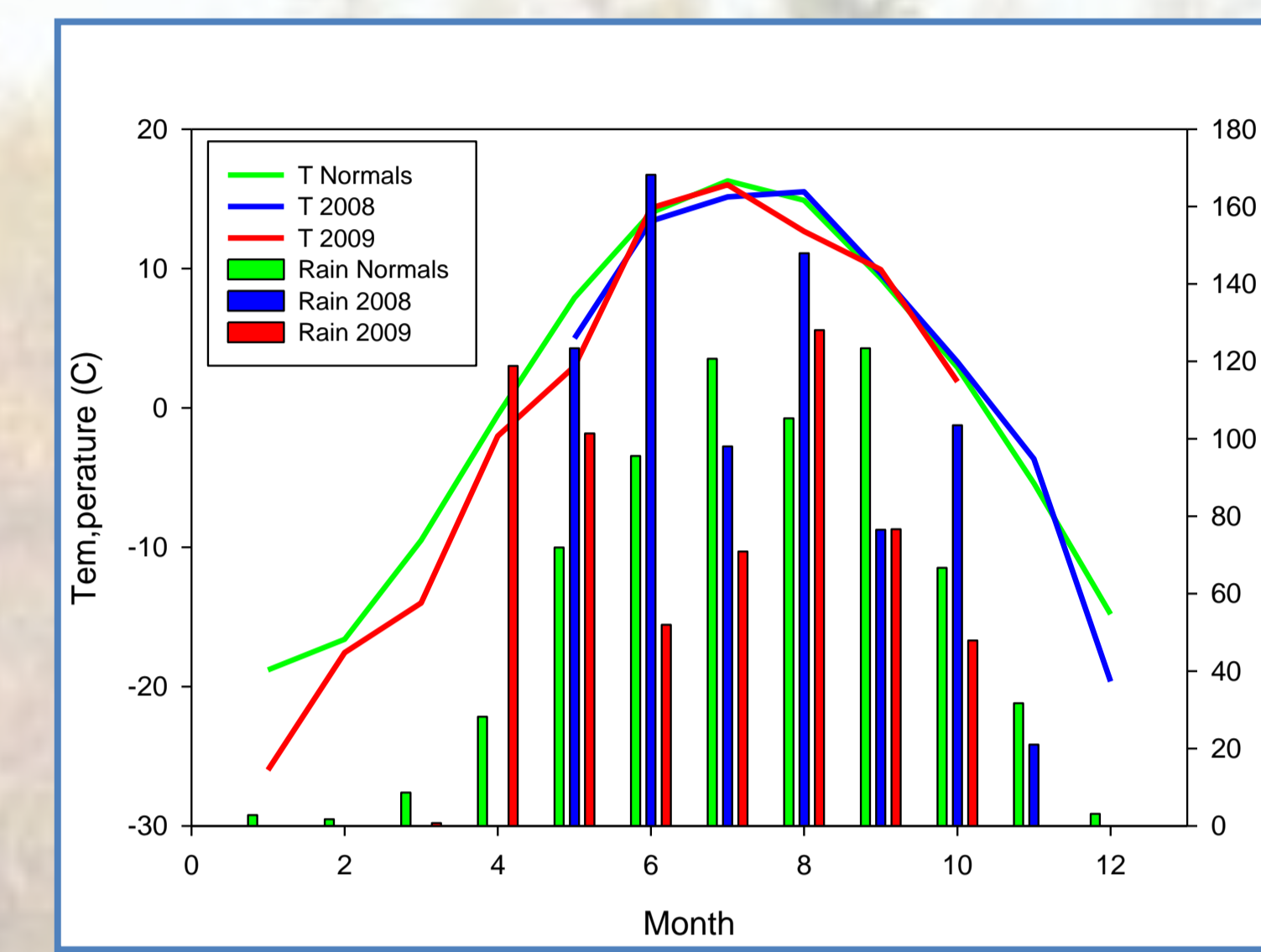
3a. Site Description

- Lac Le Caron (LLC) peatland:** Ombrotrophic bog in a humid mid-boreal climate (52° 17' 25"N; 75° 50' 15"W) in the James Bay region of North-western Quebec, Canada (Fig.1).
- Basal date approx. 7520 cal BP, with the deepest part reaching 5.35 m
 - Total area about 247 ha
 - Presence of hummocks, lawns, hollows and pools



3b. Regional Climate

- Mean annual normal (1971-2000) temperature of 0.0°C, with the coldest month being January (-18.8°C) and the warmest month being July (16.3°C) (Fig. 2)
- Mean annual normal cumulative precipitation is 961 mm, with 614 mm between May and October
- In 2008 and 2009, the May to October cumulative precipitation was 718 mm and 477 mm, respectively



3c. Measurements

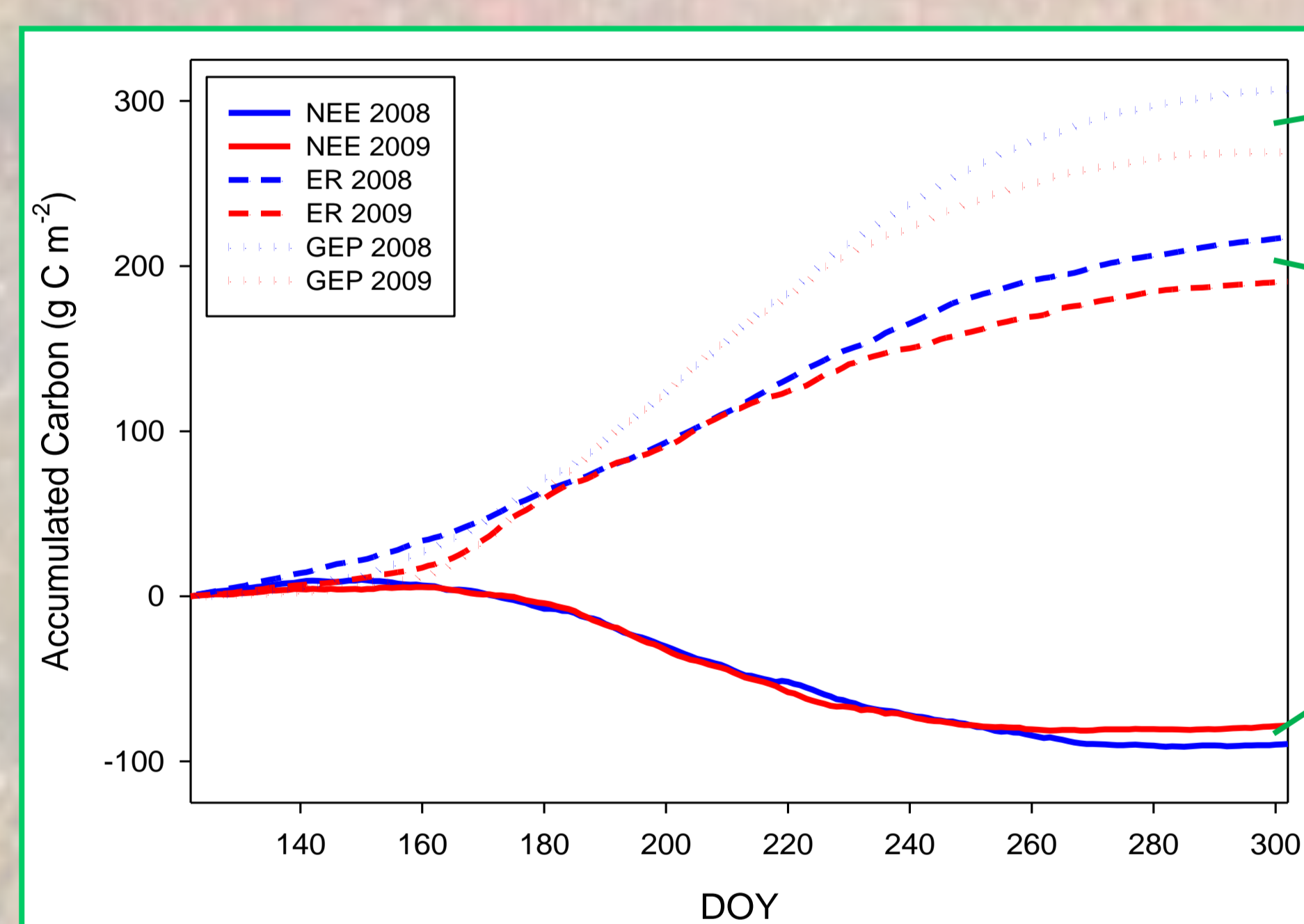
CO₂ fluxes were measured using an eddy covariance system, comprising a LI-7500 open-path IRGA and a CSAT-3 sonic anemometer; Fig. 3). Instruments were mounted 2.75 m above the ground.



→ The eddy covariance technique allows for continuous, spatially integrated flux measurements

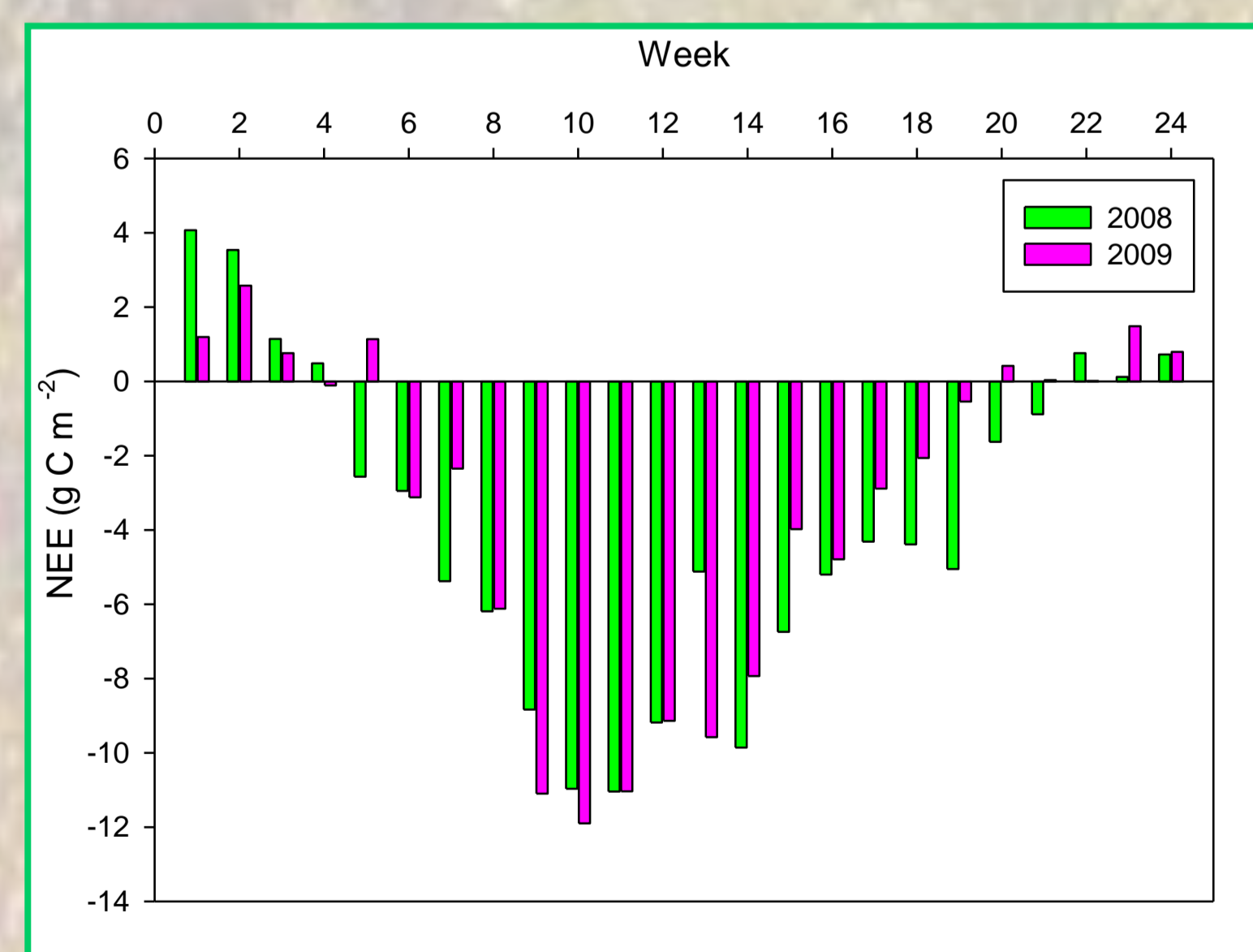
Meteorology: Air temperature and relative humidity, incoming and outgoing short- and longwave radiation, soil temperature (5, 10, 20, and 40cm), and precipitation

4.1 Comparison of Cumulative CO₂ Exchange



- May to October cumulative **GEP**:
 2008: 307.0 ± 54.3 g C m⁻²
 2009: 268.9 ± 50.8 g C m⁻²
- May to October cumulative **ER**:
 2008: 217.4 ± 45.7 g C m⁻²
 2009: 190.6 ± 43.5 g C m⁻²
- May to October cumulative **NEE**:
 2008: -89.5 ± 51.5 g C m⁻²
 2009: -78.3 ± 46.2 g C m⁻²

The CO₂ uptake period (CUP) was 143 days in 2008 and 127 days in 2009



Month	NEE 08	NEE 09	GEP 08	GEP 09	ER 08	ER 09
May	9.22	4.67	14.53	7.14	23.85	11.81
Jun	-17.08	-9.16	59.60	59.23	42.50	50.08
Jul	-40.03	-42.88	91.00	94.87	50.97	51.99
Aug	-26.93	-27.50	81.53	66.56	54.59	39.06
Sep	-15.39	-5.42	45.98	32.70	30.59	27.28
Oct	0.71	2.31	14.24	8.38	14.93	10.69

Table 1. Monthly cumulative NEE, GEP and ER (g C m⁻²).

4.2 Light Response Curves and Associated Parameters

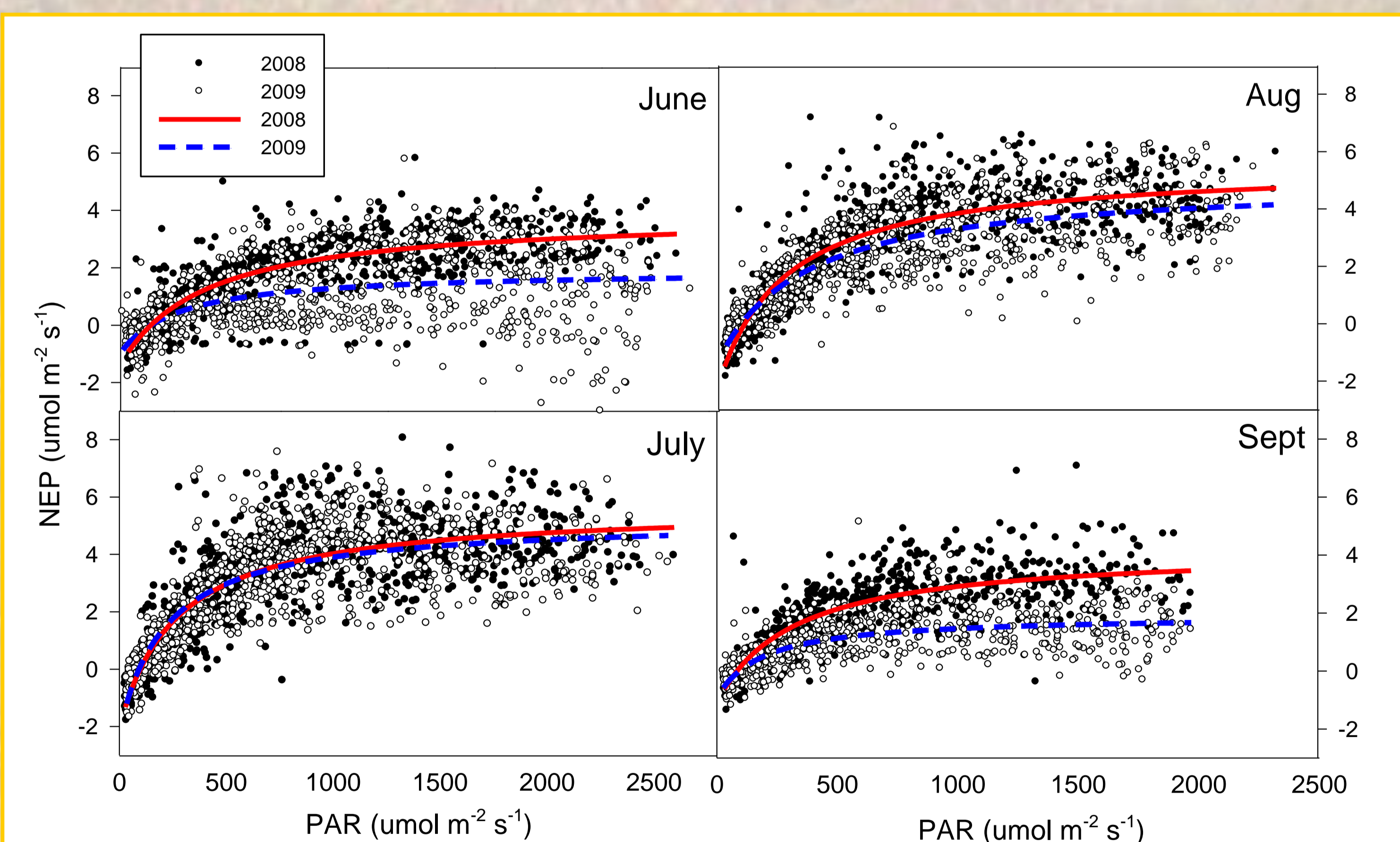


Figure 6. Monthly light response curves from June to September 2008 (black circles and red lines) and 2009 (white circles and blue lines).

Parameter	June		July		August		September		October	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
α	0.0132	0.0104	0.0287	0.0344	0.0266	0.0170	0.0166	0.0150	0.0074	0.0027
GP _{max}	5.25	2.89	7.73	7.49	7.68	6.30	5.30	2.86	2.09	1.72
R	-1.38	-0.97	-2.07	-2.24	-2.11	-1.29	-1.11	-0.94	-0.45	-0.31

Table 2. Light response curve parameters: quantum yield (α), maximum gross productivity (GP_{max}; μmol m⁻² s⁻¹) and dark respiration (R; μmol m⁻² s⁻¹).

4.3 Environmental Controls of CO₂ Flux Components

		NEE			GEP			ER		
		T _{air}	PAR	WTD	T _{air}	PAR	WTD	T _{air}	PAR	WTD
2008	Spring	0.33	0.19	ns	0.72	0.08	ns	0.92	ns	ns
	Fall	ns	0.46	0.12	0.12	0.17	0.50	0.81	0.01	0.06
	May to Oct.	0.11	0.30	ns	0.59	0.08	0.01	0.87	0.01	ns
2009	Spring	0.41	ns	ns	0.91	ns	ns	0.92	ns	0.01
	Fall	ns	0.42	ns	0.75	0.12	ns	0.91	0.02	ns
	May to Oct.	0.25	ns	0.03	0.75	ns	0.01	0.89	0.003	0.02
2008-09	Spring	0.33	ns	ns	0.84	ns	0.01	0.90	ns	0.01
	Fall	ns	0.40	0.11	0.54	0.19	0.06	0.86	0.03	0.01
	May to Oct.	0.25	0.06	ns	0.68	0.03	ns	0.88	0.004	0.01

Table 3. Change in r² value by including this variable in the stepwise regression models. Spring is May and June, Fall is September and October. "ns" means not significant at 0.05.

4.4 Result Highlights

- July and August had similar NEE
- The largest differences in NEE were observed in spring (May and June) and fall (September and October) (Table 1)
- **Temperature** explains most of the variations in **spring** NEE (Table 3):
 - Warmer temperature and early snowmelt in May 2008 led to an earlier onset of the CUP and thus higher spring GEP, which more than compensated for the higher ER
 - Although GP_{max} was higher in June 2008 than June 2009 (Table 2), lower air temperatures in much cloudier conditions in June 2008 led to similar GEP, but lower ER than in June 2009
- **Light** explains most of the variation in **fall** NEE (Table 3):
 - Although average incoming PAR was about the same in September 2008 and 2009, this variable explains most of the variation in fall NEE (Table 2), as observed in other studies
 - There is likely an interaction effect with other environmental variable (e.g. WTD, wind direction) that would explain the lower GP_{max} in September 2009 (Table 2)

5. Conclusions

This study showed that the larger cumulative NEE in 2008 is the result of a combination of earlier onset of the growing season due to warmer temperatures and earlier snowmelt, and of greater photosynthesis rates in the fall. The peak growing season months showed similar NEE in both study years, so that most of the May to October difference in NEE is related to differences in spring and fall fluxes. Spring NEE was mostly controlled by temperature and fall NEE was mostly influenced by PAR. Such findings imply that variations in temperature, precipitation and cloudiness resulting from global climate change will likely alter peatland C balance through modifications of ecosystem responses and adaptations. However, using the contemporary results to try to explain future changes in peatland carbon balance in response to climate change is made difficult because other peatland biophysical properties may be modified through ecological changes (e.g. to surface microtopography, plant communities, etc.).

References

Gorham E (1991) Northern peatlands - Role in the carbon cycle and probable responses to climatic warming. *Ecological Applications*, 1, 182-195.
 Roulet NT (2000) Peatlands, carbon storage, greenhouse gases, and the Kyoto Protocol: Prospects and significance for Canada. *Wetlands*, 20, 605-615.