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Controls on Ecosystem Respiration at an Ombrotrophic Bog

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Introduction

Carbon accumulation in terrestrial ecosystems is the net result of two large mass flows: the uptake of CO_2 from the atmosphere by photosynthesis [P] and the loss of carbon by respiratory processes called ecosystem respiration [ER], Figure 1. ER is therefore an important component of the carbon cycle and knowledge of the environmental factors that control it is important.

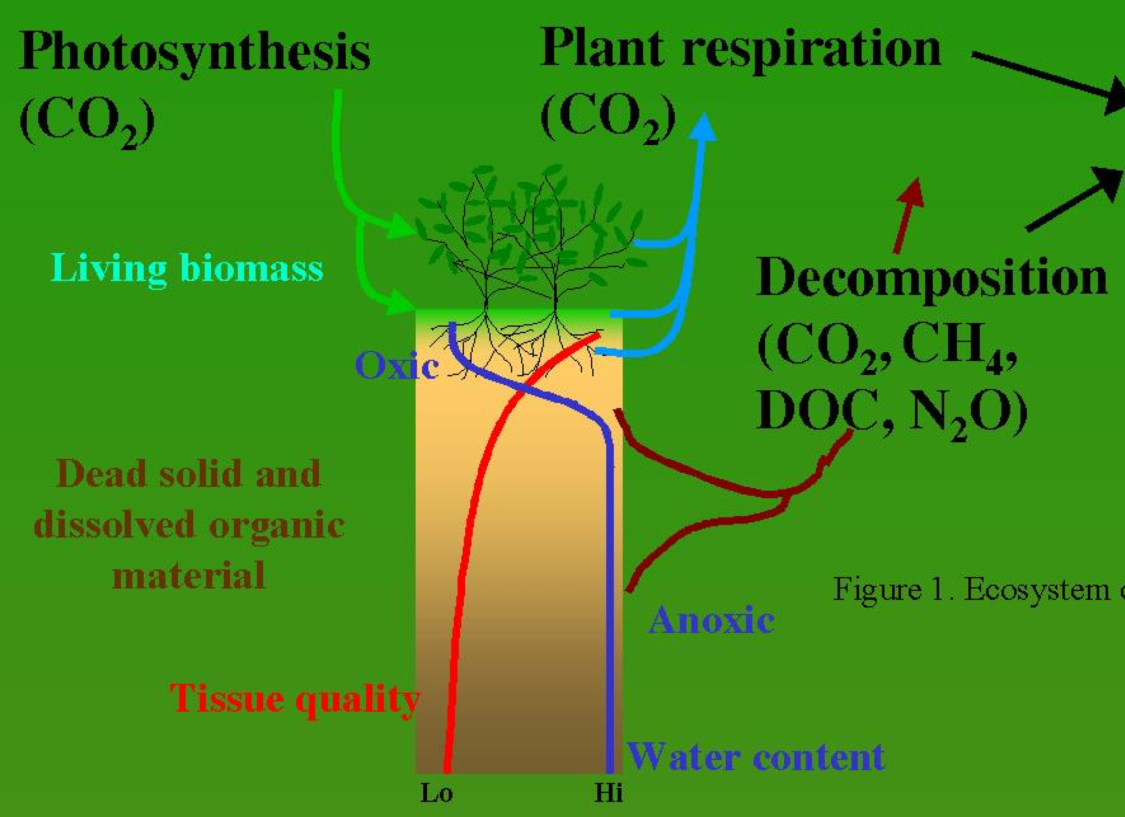

Figure 1. Ecosystem carbon exchange processes

In this study we examined ER at the Mer Bleue bog and its relationship with two main environmental driving variables, *temperature and water*. Data were collected over 4 growing seasons, thus encompassing a wide range of conditions. Traditionally, it is believe that water table (WT) is a strong control over peatland functioning. Here we show that temperature (T) is the main determinant of ER and that WT has little or no influence on ER.

Methods

Mer Bleue is a large (2800 ha) ombrotrophic (rain fed) bog located 2 km east of Ottawa, Ontario (Fig. 1). The hummock-hollow surface microtopography (hummocks cover 70%) is blanketed by *Sphagnum* mosses, above which ericaceous shrubs grow to a height of 30 cm, with a maximum leaf area index of 1.3. Peat depth in the bog varies from 2-6 m.

We used the eddy covariance technique to measure the net exchange of CO_2 (NEE) between the bog surface and atmosphere with a fast response sonic anemometer and infrared gas analyser. Nighttime measurements of NEE are unaffected by photosynthesis and were taken to represent ER. The data used in this study were nighttime averages of 30-min fluxes where at least six 30-min periods existed for a given night. A 'night' was the dark period centered on 2400 hours EST. Water table and temperature data were averaged over each night.

Results

Seasonal trends in ER, soil temperature and WT depth suggest a closer correspondence between T and ER than between WT and ER. T and ER both show a pattern of smaller values in spring and fall and peaking in mid-summer (Fig 2).

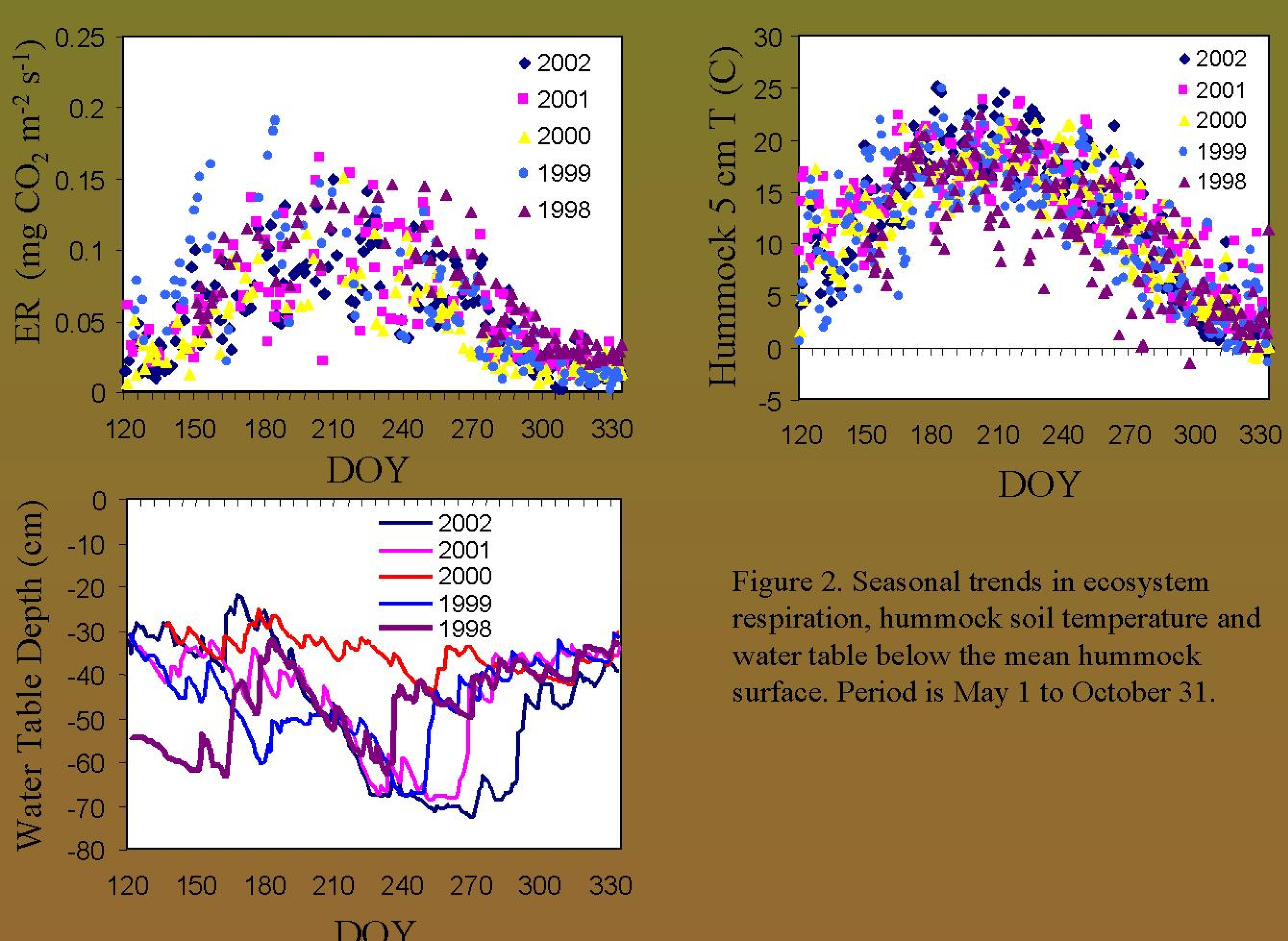

Figure 2. Seasonal trends in ecosystem respiration, hummock soil temperature and water table below the mean hummock surface. Period is May 1 to October 31.

ER showed considerable night-to-night variation; again the level of variation was more consistent with that for the soil temperature than for WT. The seasonal trend in WT varied considerably between years. These qualitative assessments of ER, T, and WT suggest that high frequency variations in ER are likely strongly related to T and that seasonal or annual variation may be influenced by WT.

Indeed, ER was closely correlated with soil temperature and poorly correlated with WT for all data pooled (Fig. 3). Near surface (5-10 cm) hollow and air temperature (50 cm above hummock) produced similar relationships with ER as the hummock surface temperature (not shown). Relationships for soil temperatures from deeper in the profile degraded with depth.

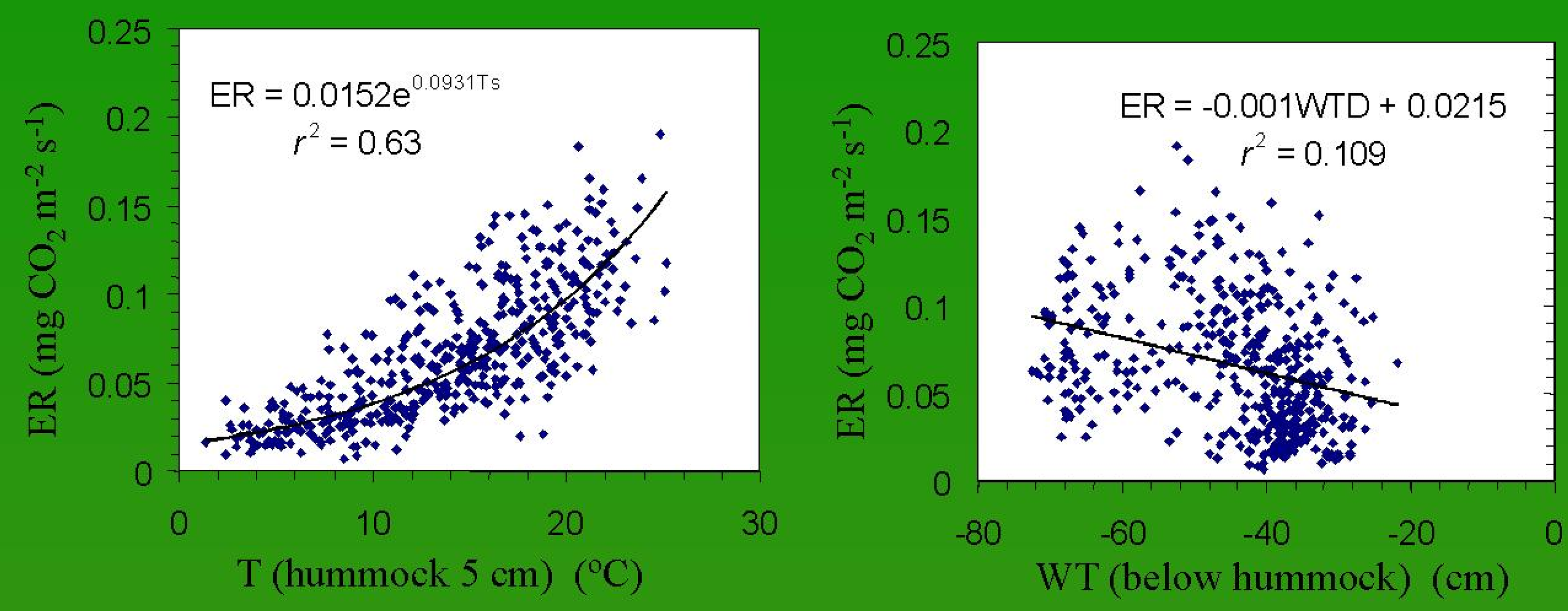

Figure 3. Relationship between ecosystem respiration (ER) and hummock soil temperature (T) and water table (WT).

Data were sorted into three classes of water table: shallow >-40 cm, intermediate -40 to -60 cm, and deep <-60 cm (measured from hummock surface). Relationships between ER and soil temperature were similar for the shallow and deep classes (Fig. 4). Calculations of the Q_{10} value (change in rate of respiration for a 10 degree change in temperature) for these two groups were similar (shallow=2.5 and deep=2.1); this difference was considerably less than the range in Q_{10} derived for the various hummock and hollow soil temperatures.

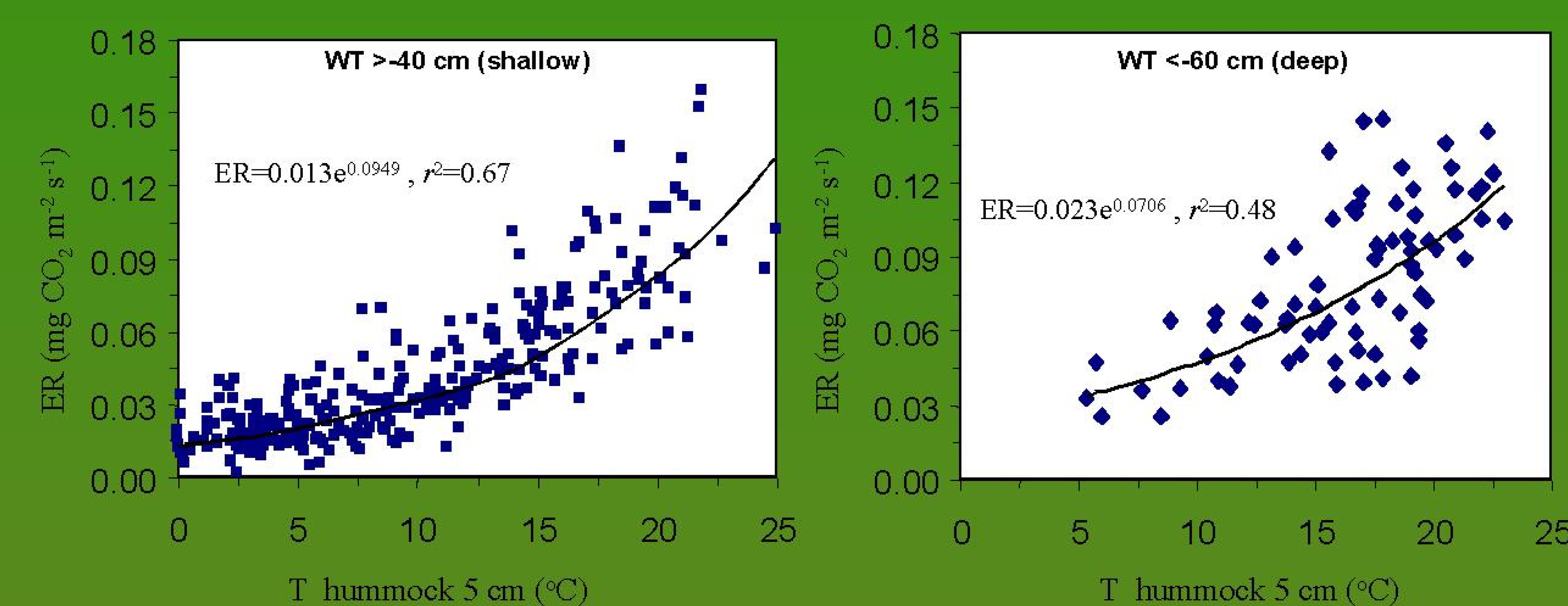

Fig. 4. Relationship between ER and hummock soil temperature for periods when the water table was shallow (>-40 cm) and deep (<-60 cm). Best fit first order exponential relationship is shown.

During the summer of 2000 Mer Bleue was subject to an extended dry period. For the 2002 summer we divided the data set into two time periods when the WT was shallow (DOY 149-190) and deep (DOY 217-289). For these two periods we plotted ER against WT (Fig. 5). The range and mean of ER for these two periods was similar.

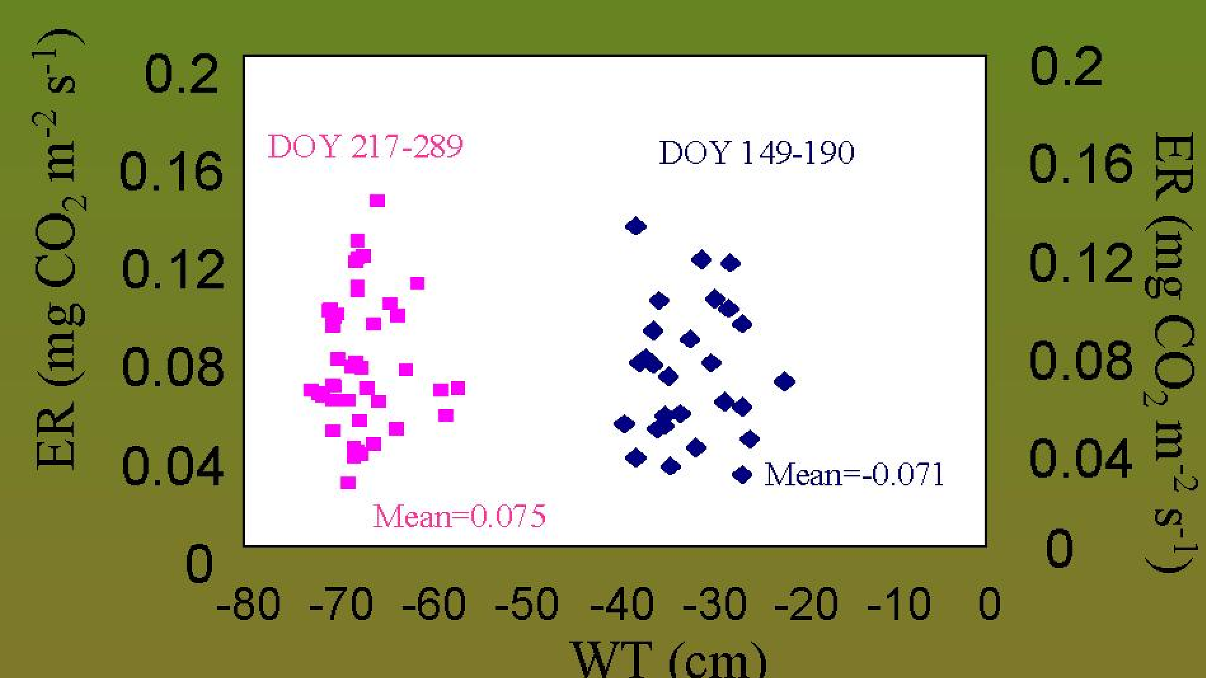

Fig. 5. Distribution of ER for two periods in 2002 with contrasting WT. WT was high during Day Of Year 149-190 (20≤WT≤40 cm), while DOY217-289 represented the late summer drought period with deep (≥60 cm) WT.

Laboratory measurements of CO_2 production from core samples indicated that upper peat samples were more productive than deeper peat samples (Fig. 6). As well, only near surface samples showed a strong relationship between production and moisture content.

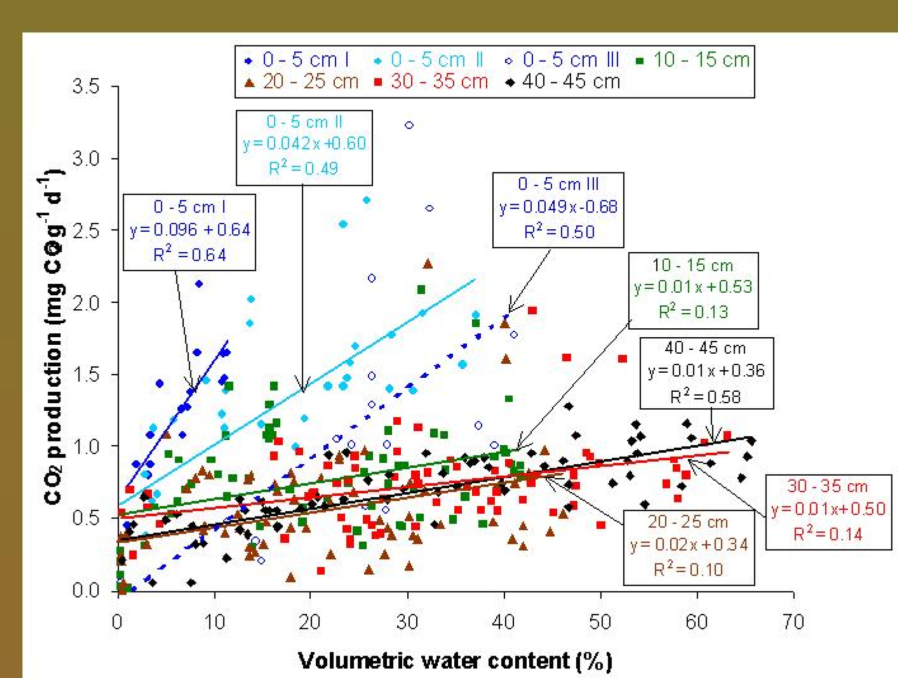

Fig. 6. Rates of CO2 production measured in peat core samples as a function of moisture content. 0-5 cm I, II, and III represent three separate drying cycles for the 0-5 cm core samples. Drying cycles for the other core depth were pooled in to single data set for each layer. Best fit linear relationship is shown and coefficient of determination.

Conclusions

ER at the Mer Bleue bog is more strongly influenced by near surface environmental temperatures than changes in water table depth. Although further experimentation is needed to determine the true controls on ER, the lack of a WT response was surprising. We believe there are several contributing factors for this behaviour.

- Mer Bleue is a 'dry' peatland; mean WT during four summers of observation was -45 cm below the average hummock surface; previous studies that have shown an ER response to WT were conducted almost exclusively in wetter environments,
- There is a strong belief that the most easily decomposable material is near the top of the peat column, where the moisture content varies within tight limits; material below the mean WT depth is more recalcitrant and likely contributes significantly less to total ER (ER responses to T at depth support this hypothesis),
- A significant portion of ER may be from plant respiration, which is controlled to a large extent by photosynthesis, which is itself a strong function of temperature,
- Finally, availability of oxygen for a unit change in WT (i.e., pore space) decreases non-linearly with depth, thus potentially inhibiting microbial respiration.

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