Partitioning Peat Respiration in the Catotelm

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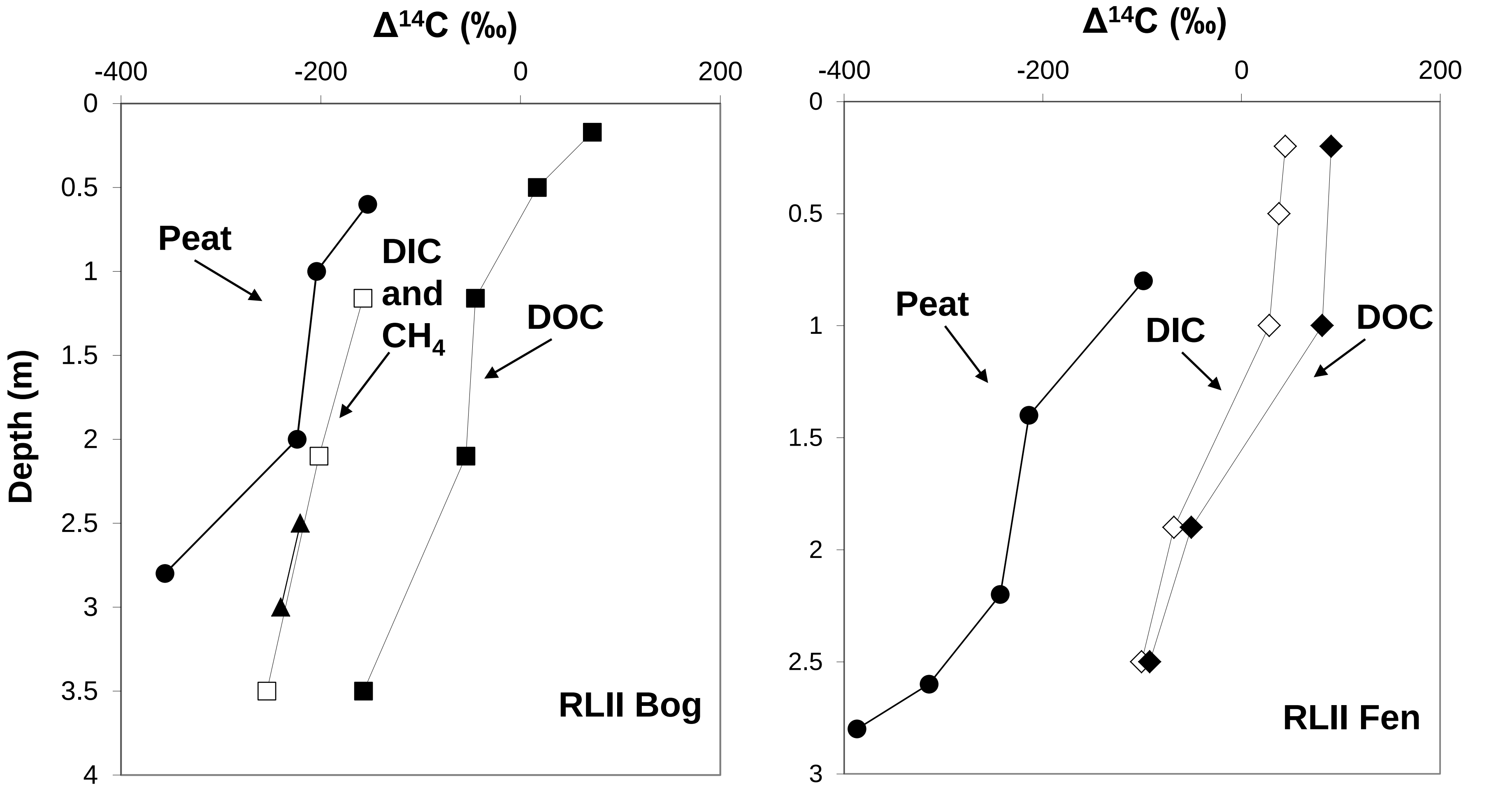
Introduction

- Peatland importance
  - Large carbon sinks with 1/3 of the total soil carbon
  - Recognizing high risk environments within peatlands
- Bogs vs. fens
  - pH, DOM characteristics, vegetation, water table
- Pathways
  - Fractionating: methanogenesis
  - Non-fractioning: oxic respiration, HMW organic matter degradation, other electron acceptors (sulfate, nitrate, iron)
- Oxygen and labile OM present in fens more than bogs due to plant roots
- Methane loss higher in fens than bogs

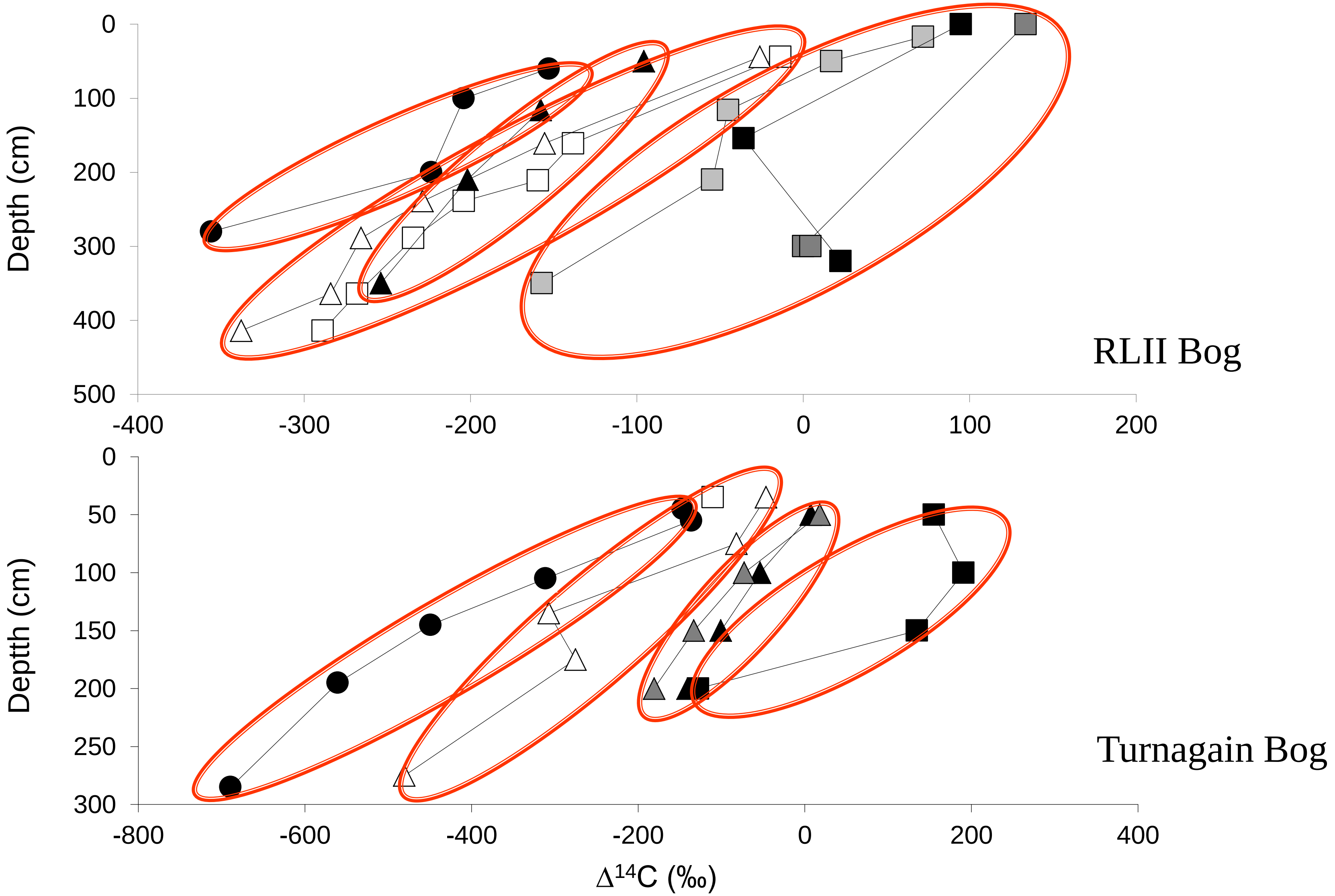
Radiocarbon Work



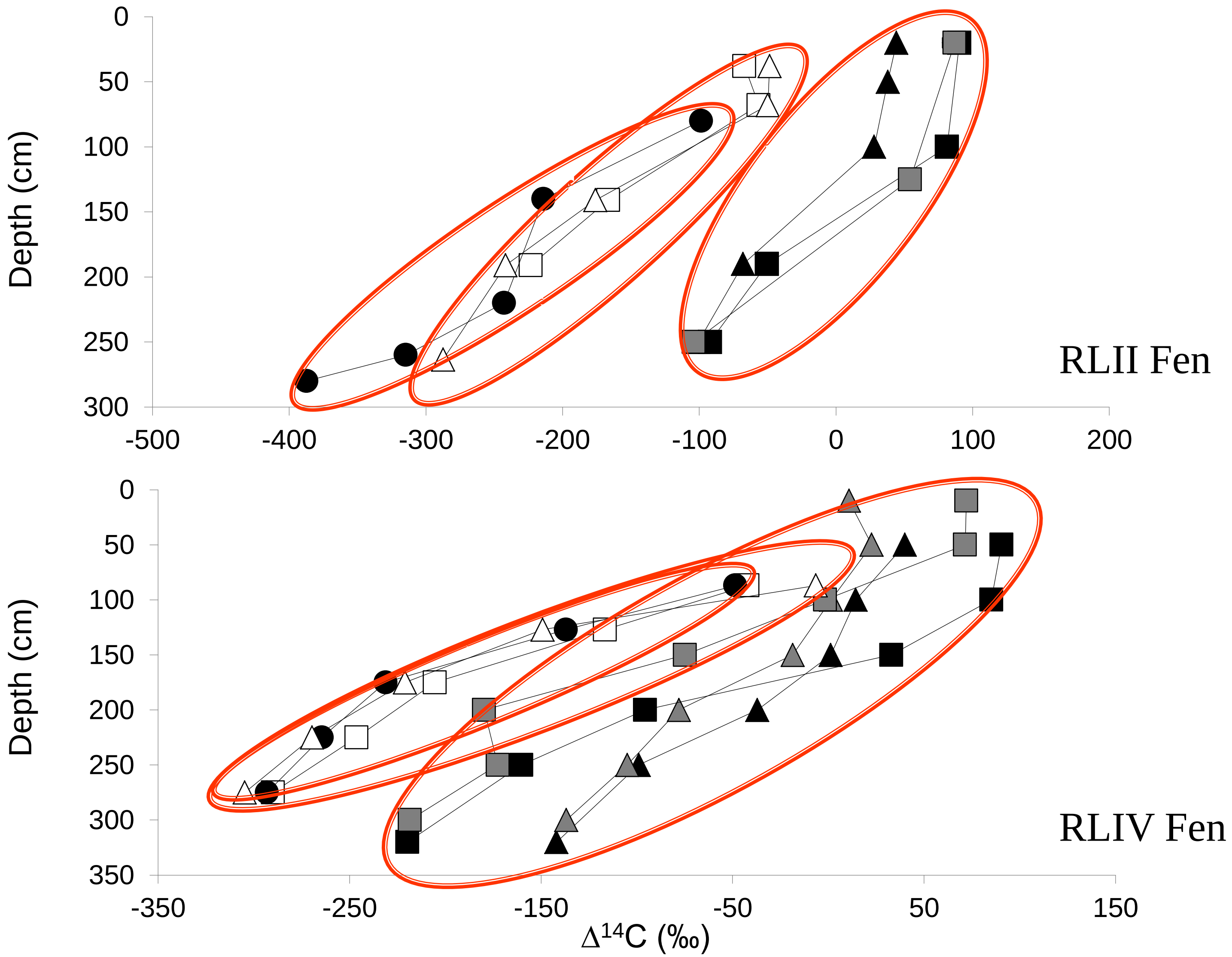
Incubations (Radiocarbon Results)

- Incubations done to examine DOC sources and quality differences from field samples
- Peats were rinsed (to remove any DOC already present) and place in incubation vials and made anaerobic
- Incubations were run for ~150 days and radiocarbon of the respiration products and DOC were analyzed and compared to samples of peat, DOC, and DIC taken in the field
- Differences in $\Delta^{14}C$ values between pore water DOC and incubation DOC would suggest that:
  - Pore water DOC from certain depths in the field has other sources than just the peat at those depths
  - If the field pore water DOC is more modern than produced incubation DOC then some DOC in the field may be advected downward from more modern, surficial layers

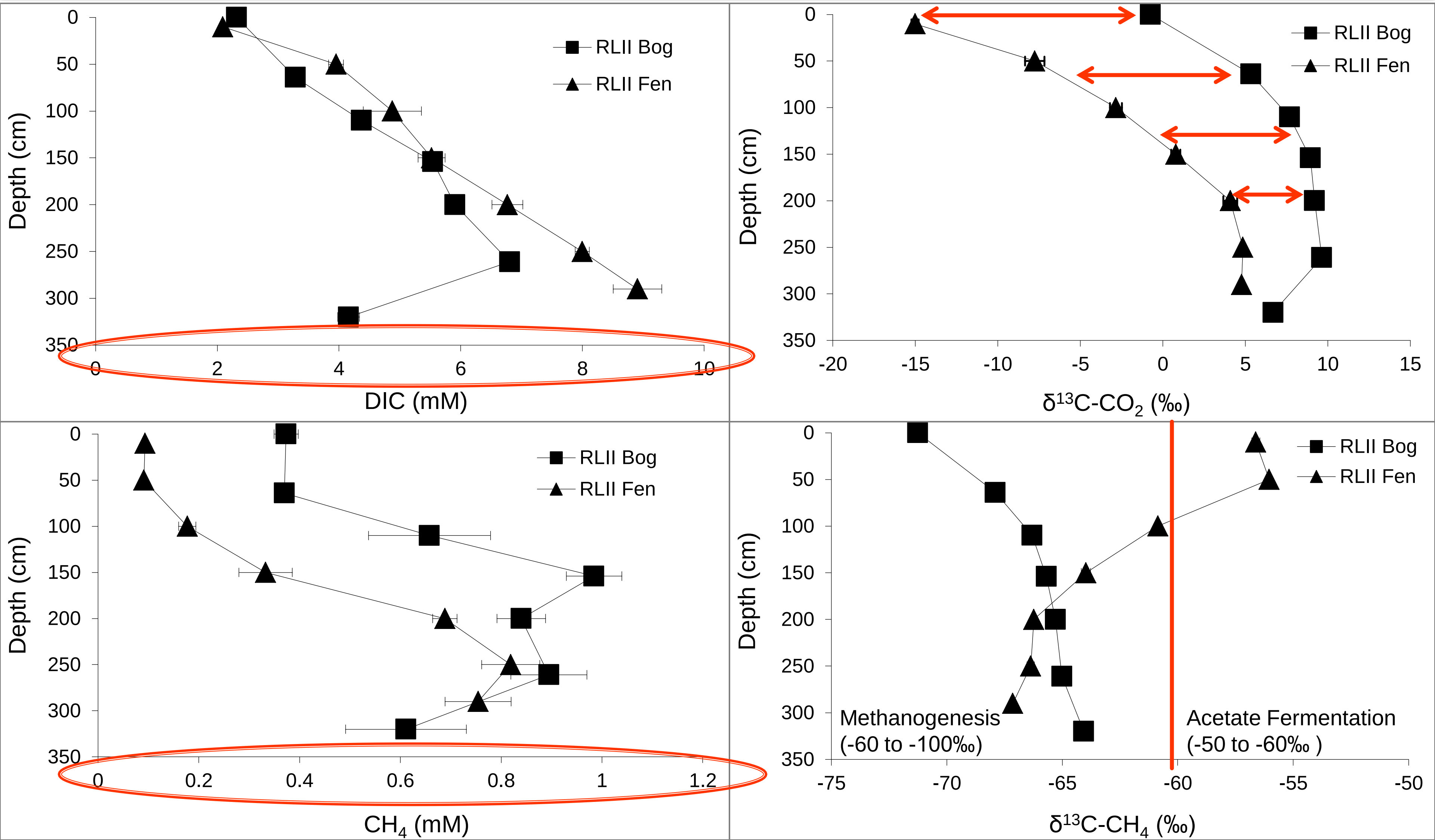
Bog Incubations



Fen Incubations



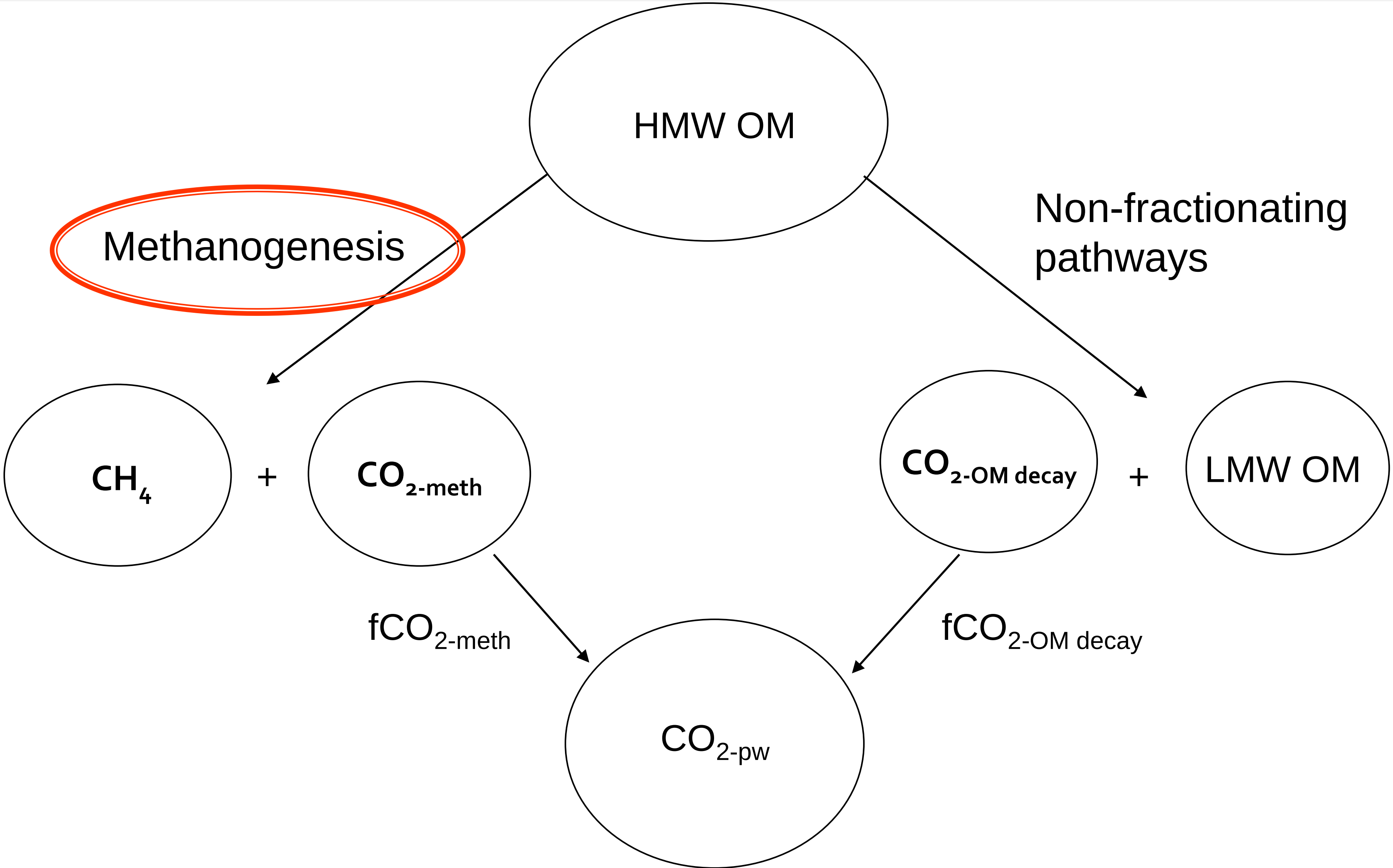
Pore water CH_4 and CO_2 concentration and isotope data



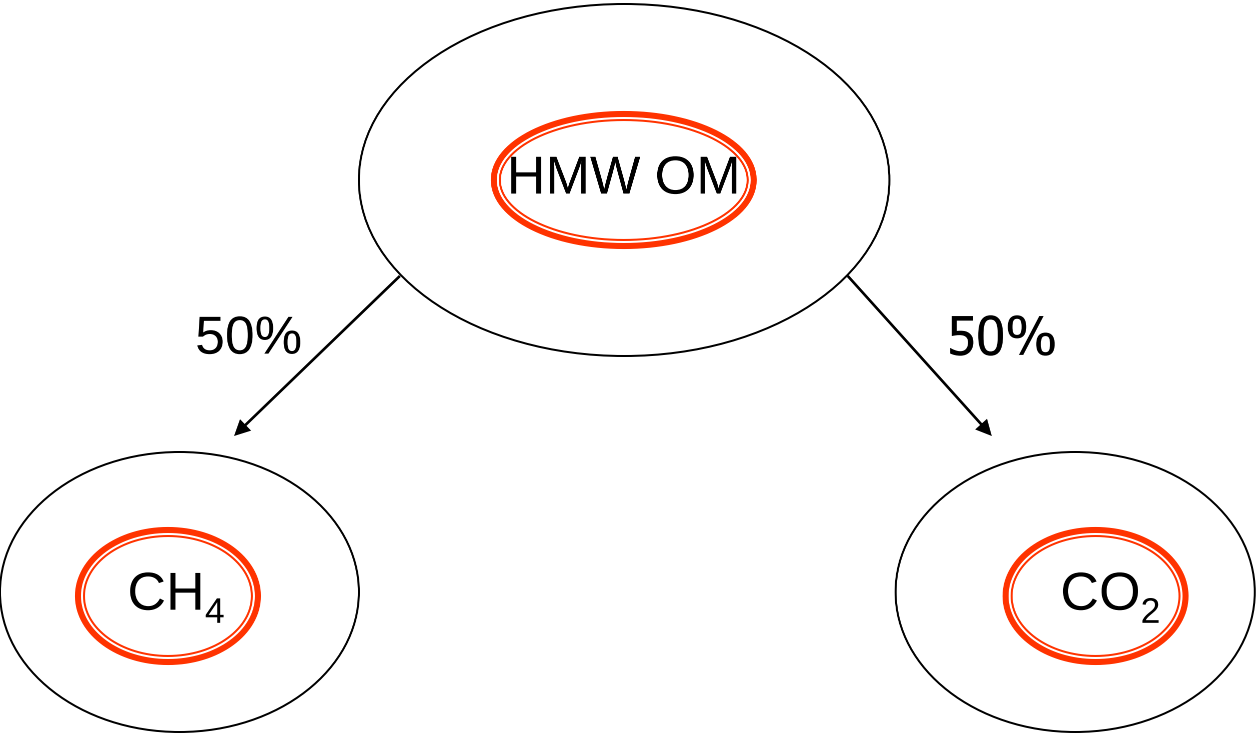
Objectives and Assumptions

- Radiocarbon results show that fens have more labile DOC than bogs and in the field modern DOC is advected downwards
- Methanogenesis produces CH_4 and CO_2 at a 1:1 ratio
  - Non-fractionating pathways (HMW OM fermentation, sulfate reduction, oxic respiration) produce CO_2 only
  - CH_4 escape via plant roots and pore water due to low solubility
- Groundwater movement in GLAP is advection dominated
  - Advection discriminates less between light and heavier isotope species and diffusive fractionation is not taken into account in our model
- We want to find:
  - Fraction of CO_2 from fractionating (methanogenisis) and non-fractionating (HMW OM fermentation, other e^- acceptors, oxic respiration)
  - Amount of methane escaping from pore water either to atmosphere or to acrotelm

Carbon Pools in a peatland system



Isotope Mass Balance

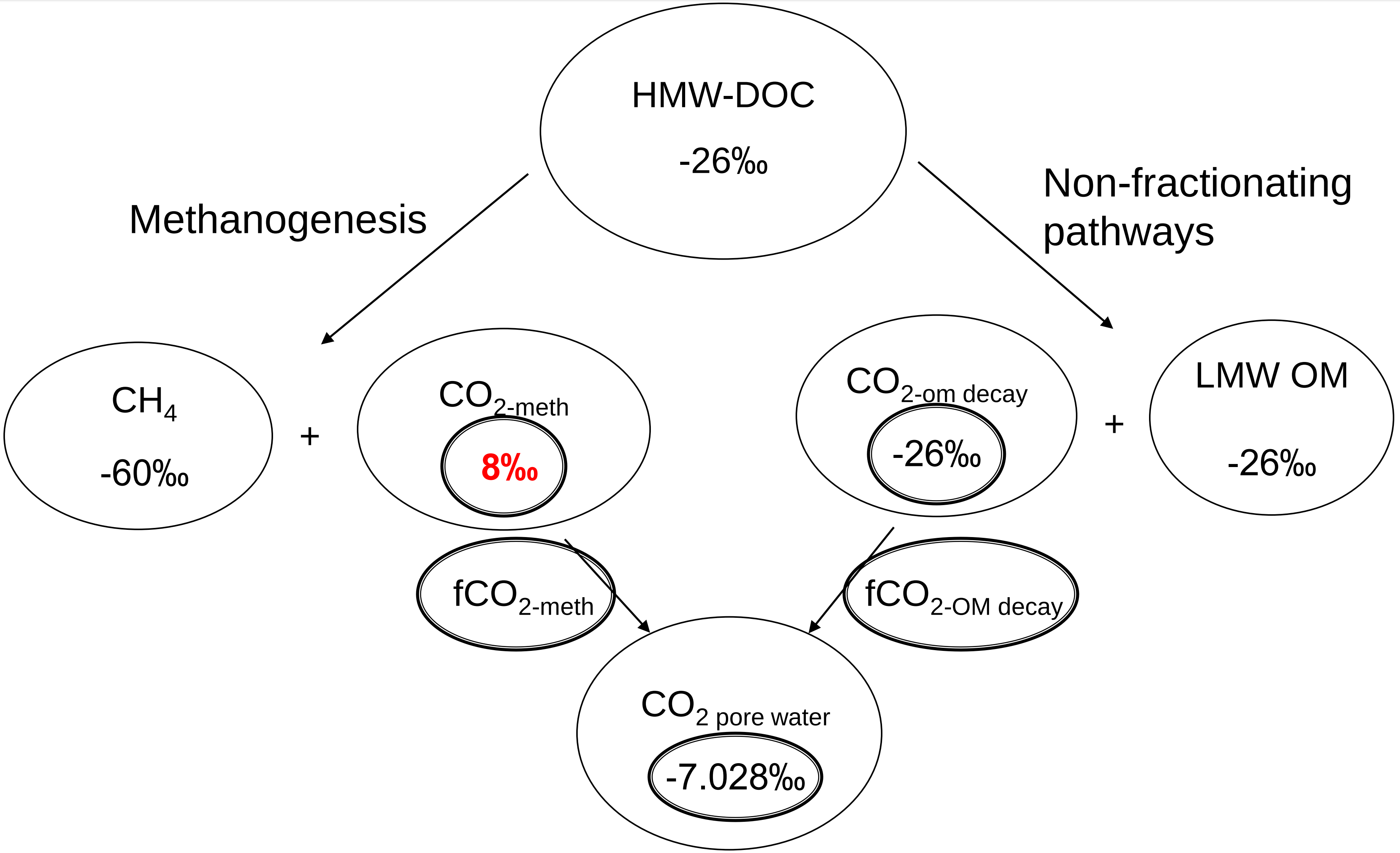


$$(\delta^{13}C\text{-}OM \times 1) = (0.5 \times \delta^{13}C\text{-}CH_4) + (0.5 \times \delta^{13}C\text{-}CO_{2\text{-}meth})$$

$$(-26‰ \times 1) = (0.5 \times -60‰) + (0.5 \times ?)$$

- Assume 1:1 ratio of CO_2 and CH_4 production from methanogenesis (Barker 1936)
- The $\delta^{13}C$ of dissolved HMW OM (high molecular weight organic matter) was measured to be –26‰.
- If the $\delta^{13}C$ value of methane produced is –60‰, then the value of CO_2 produced, must by mass balance bear an isotopic value of +8‰.
- CO_2 can also be produced from non-fractionating pathways

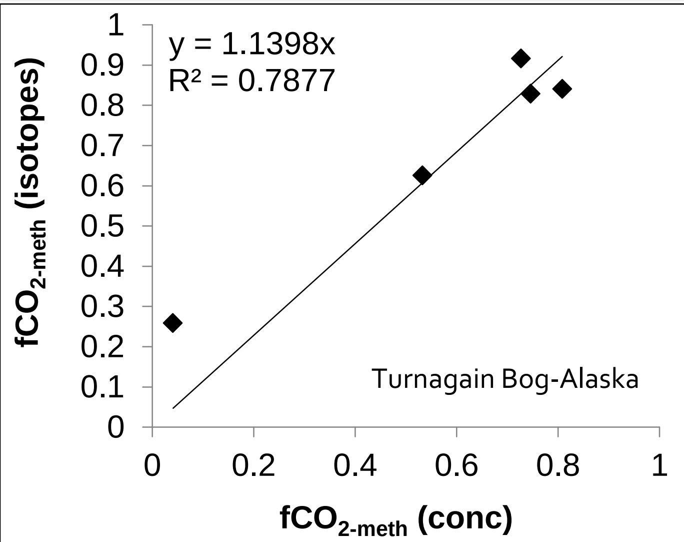
Isotope Mass Balance

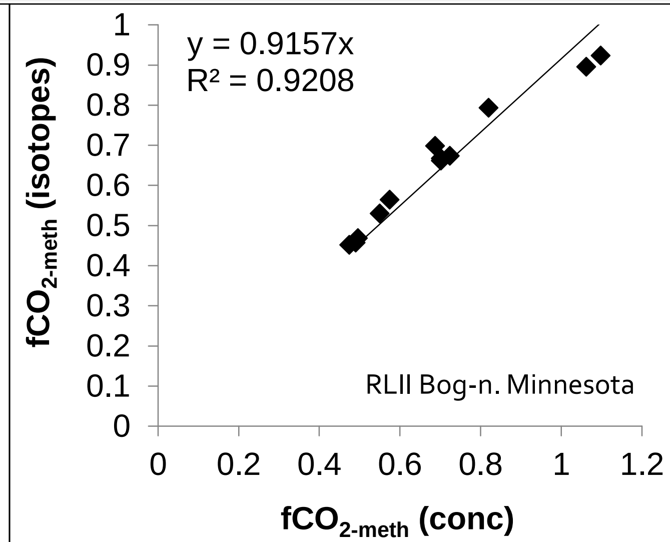


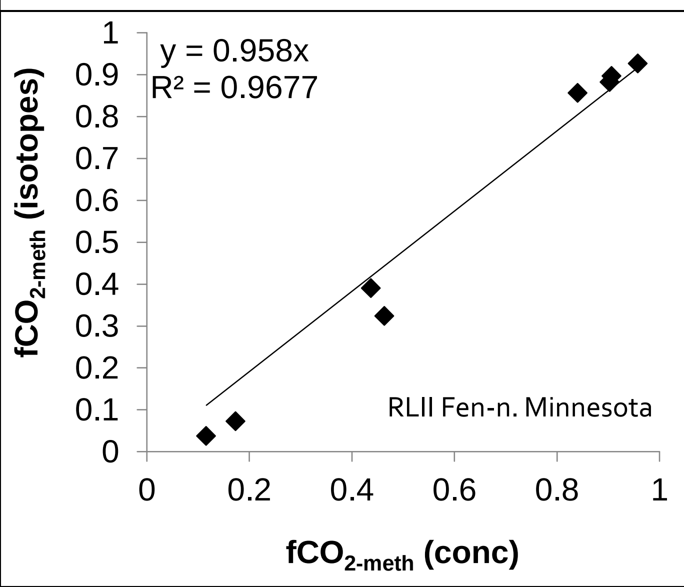
Proportion of CO_2

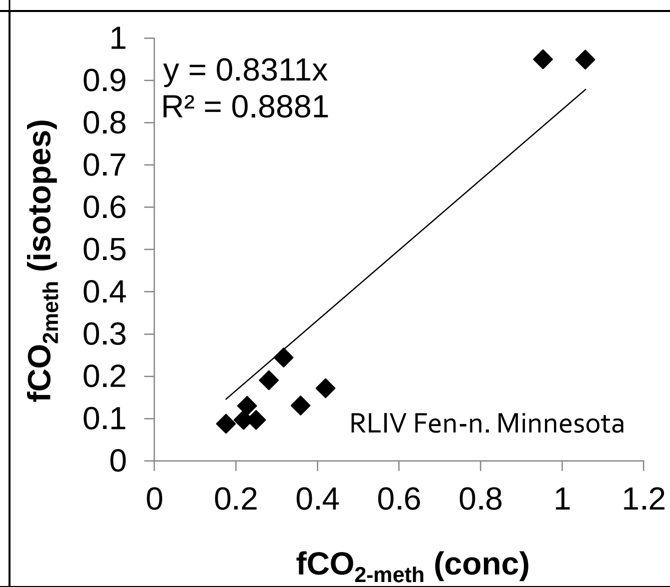
- $(\delta^{13}C\text{-}CO_{2\text{-pw}}) \times (1) = (-26‰) \times (fCO_{2\text{-OM decay}}) + (\delta^{13}C\text{-}CO_{2\text{-meth}}) \times (fCO_{2\text{-meth}})$ (1)
- $(-7.028‰) \times (1) = (-26‰) \times (fCO_{2\ \text{OMdecay}}) + (8\ ‰) \times (fCO_{2\ \text{meth}})$
- $fCO_{2\ \text{OMdecay}} + fCO_{2\ \text{meth}} = 1$ (2)
- $(\delta^{13}C\text{-}CO_{2\text{-pw}}) \times (1) = (-26‰) \times (1 - fCO_{2\text{-meth}}) + (\delta^{13}C\text{-}CO_{2\text{-meth}}) \times (fCO_{2\text{-meth}})$
- $(-7.028‰)(1) = (-26‰)\ (1 - fCO_{2\ \text{meth}}) + (8\ ‰)(fCO_{2\ \text{meth}})$
- $0.558 = fCO_{2\ \text{meth}}$
- $0.442 = fCO_{2\ \text{OMdecay}}$

Incubations (Mass Balance Results)



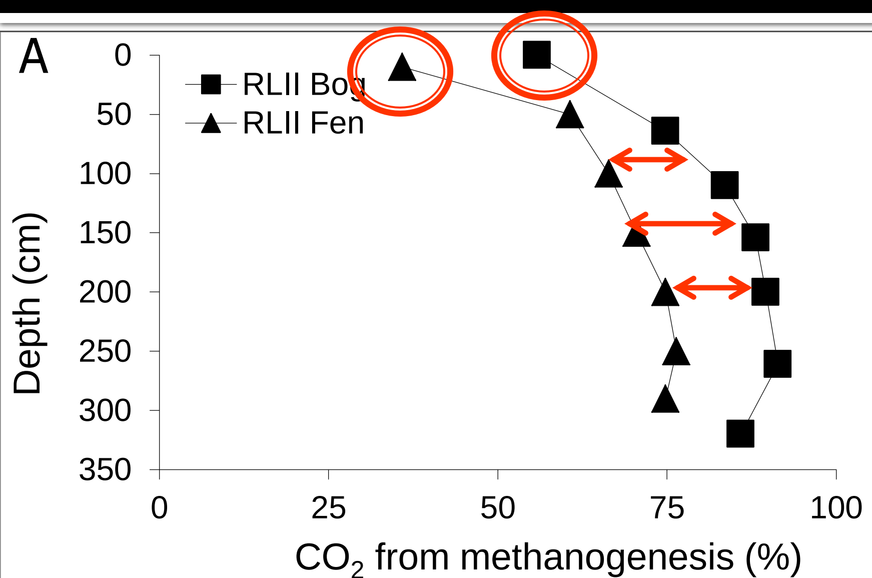


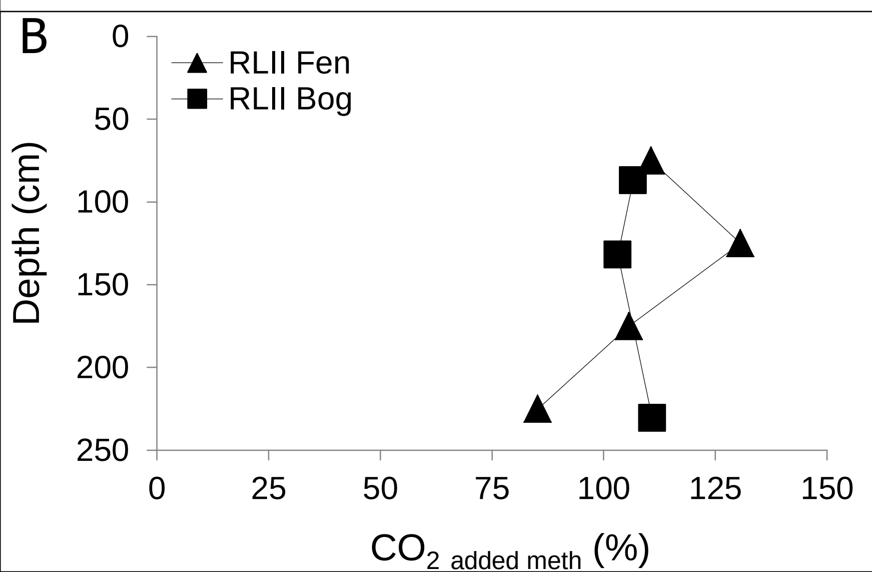




- The different data points represent peat vials from different depths. The fraction of CO_2 produced from methanogenesis (fCO_2 meth) was determined using either the isotope mass balance model (y-axis) or the concentrations of CH_4 and CO_2.
- Dividing the concentration of CH_4 by the CO_2 in the vial yields the fraction of CO_2 produced from methanogensis from production measurements (x-axis).
- More CO_2 from meth in surficial peats, opposite from pore water depth trends

Amount of CO_2 from methanogenesis





•Graph A values are calculated using bulk pore water $\delta^{13}C\text{-}CO_2$ values which includes pore water that has been advected downward so carries some surface $\delta^{13}C\text{-}CO_2$ values

•Graph B values are calculated using calculated $\delta^{13}C\text{-}CO_2$ from within depth intervals to remove any downward advected surficial $\delta^{13}C\text{-}CO_2$

•In Carex-dominated fen, 40% of CO_2 comes from methanogenesis at surface depths and amounts increase to 75% with depth (~100 % within depth intervals)

•In Sphagnum-dominated bog, 60% of CO_2 comes from methanogenesis at surface depths and amounts increase to 90% at depths (~100% within depth intervals)

•$\delta^{13}C\text{-}CO_{2\text{-added}} = ((CO_{2\text{-bottom}} * \delta^{13}C\text{-}CO_{2\text{-bottom}}) - (CO_{2\text{-top}} * \delta^{13}C\text{-}CO_{2\text{-top}})) / CO_{2\text{-added}}$

•$\delta^{13}C\text{-}CO_{2\text{-added and}}$ $^{13}C\text{-}CH_{4\text{-added}}$ applied to:
$(\delta^{13}C\text{-}CO_{2\text{-pw}}) \times (1) = (-26‰) \times (1 - fCO_{2\text{-meth}}) + (\delta^{13}C\text{-}CO_{2\text{-meth}}) \times (fCO_{2\text{-meth}})$

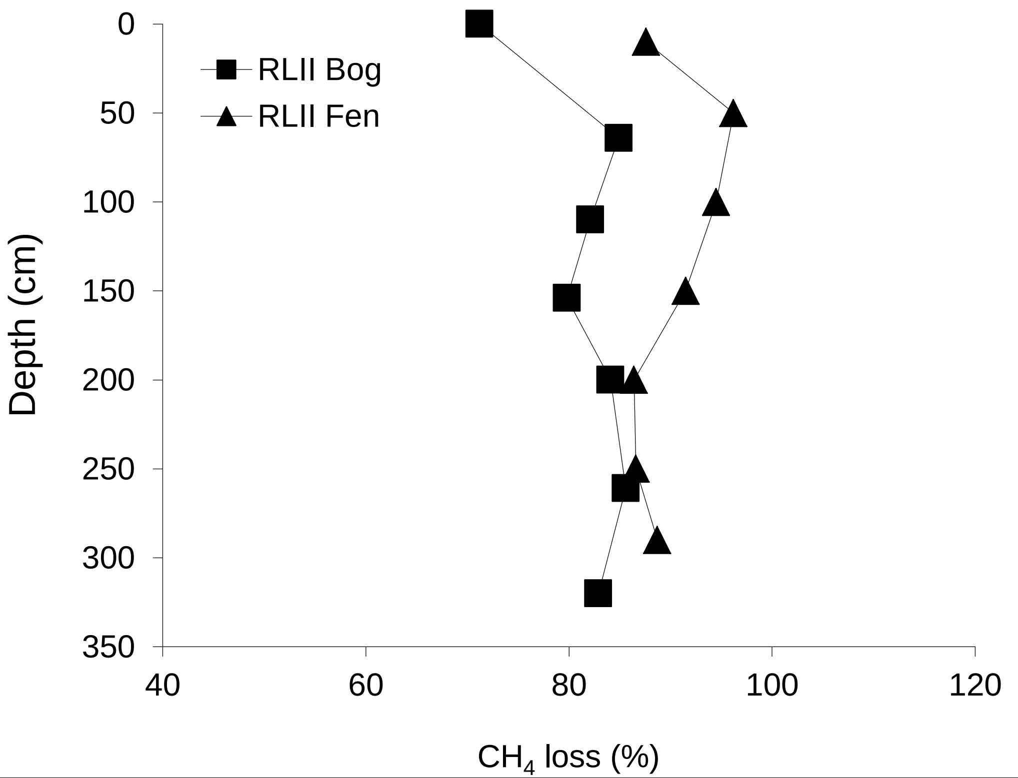
Methane Escape

- Using the fraction of CO_2 formed from methanogenesis, we can determine the amount of methane that should be formed (1:1 ratio)
- $fCO_{2\text{-meth}} * CO_{2\text{-conc}} = CO_{2\text{-meth}}$
- The CO_2 produced from methanogenesis should equal the CH_4 from methanogenesis, but we only measure about a 1/10 of the methane concentration that we expect
- Produced methane – Measured methane = Fugitive methane
- Fugitive methane / Produced methane = Fraction lost
- Looking at the methane that should be formed and the methane that is present tells us the percent methane that is leaving our system

Amount of methane loss

Sphagnum vegetation characteristic of bogs

Carex vegetation characteristic of fens



- Fens have lower amounts of CO_2 from methanogenesis than bogs, but higher amounts of meth loss

•Both bogs and fens showed 85–100% of methane loss from pore waters (only about 10–20% of the produced CH_4 remains)

•Methane release from depressurization of pore water resulting in episodic ebullition (Glaser et. al. 2004)

•Vascular plants may mediate significant methane loss (Knapp and Yavitt 1992) and contribute to more CH4 production due to labile DOC contribution from plant roots (Whiting and Chanton 1992)

•Overall, more labile DOC may contribute to higher rates of fractionationing and non-fractionating pathways

Conclusions

- CO_2 sources in a peatland environment can be partitioned with the measured $\delta^{13}C$-CO_2 of the pore water and the calculated $\delta^{13}C$-CO_2 from methanogenesis

- Bogs showed a higher percentage of CO_2 generated from methanogenesis and a lower percentage of CO_2 from non-fractionating pathways compared to fens.

- In our system, additional CO_2 most likely from either oxic respiration, HMW OM fermentation, and/or sulfate reduction

- All additional, measured electron acceptors (Fe^{3+}, NO_x, SO_4^{2-}) were extremely low; however, low sulfate concentrations have still been shown to contribute to respiration (Keller and Bridgham 2007).

- Most respiration below 50 cm (catotelm) in both bog and fen was from methanogenesis, the upper 50 cm (acrotelm) is a more complex environment due to plant roots, mixed redox zones, more labile DOM. These difference were more pronounced in fens than bogs suggesting fens to be higher risk environments for changes in climate.

- Fens showed a higher percentage of CH_4 loss than bogs possibly due to the presence of long Carex roots.

Thank you!

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