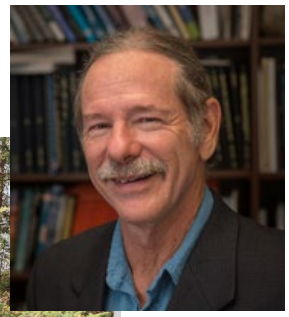
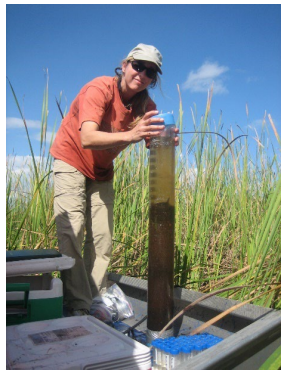
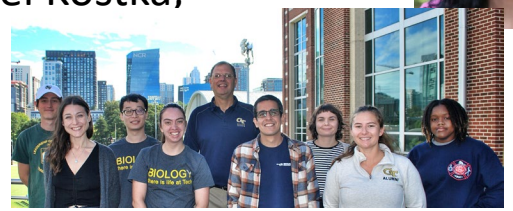
Combining a decade of results from SPRUCE and Stordalen Mire Sweden to understand the processes controlling methane production in bog peat.

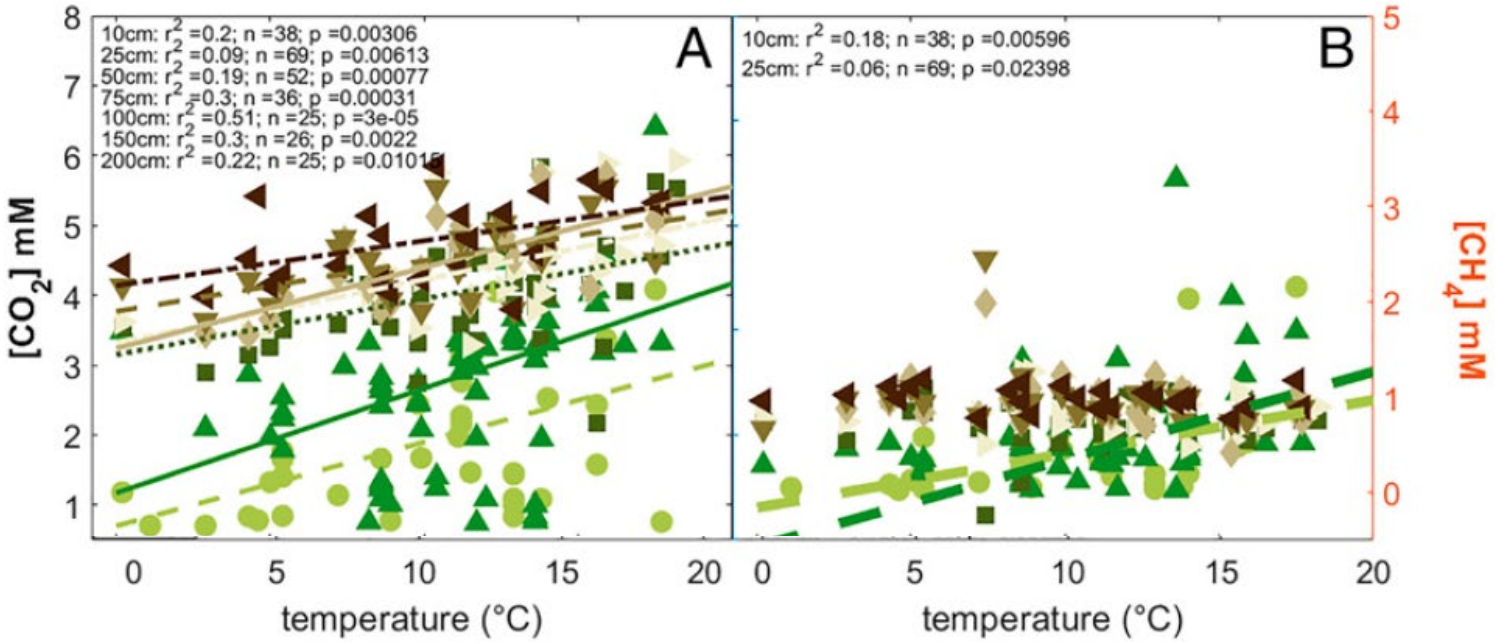
Rachel (Wilson) Younge, Jeff Chanton, Samantha Bosman, Alexandra Cory, Beth Holmes, Claire Wilson, Malak Tfaily, Chris Schadt, Joel Kostka, Katherine Duchesneau, Caitlin Petro

If you've been at the site, you might have observed our piezometer nests out in the enclosures.

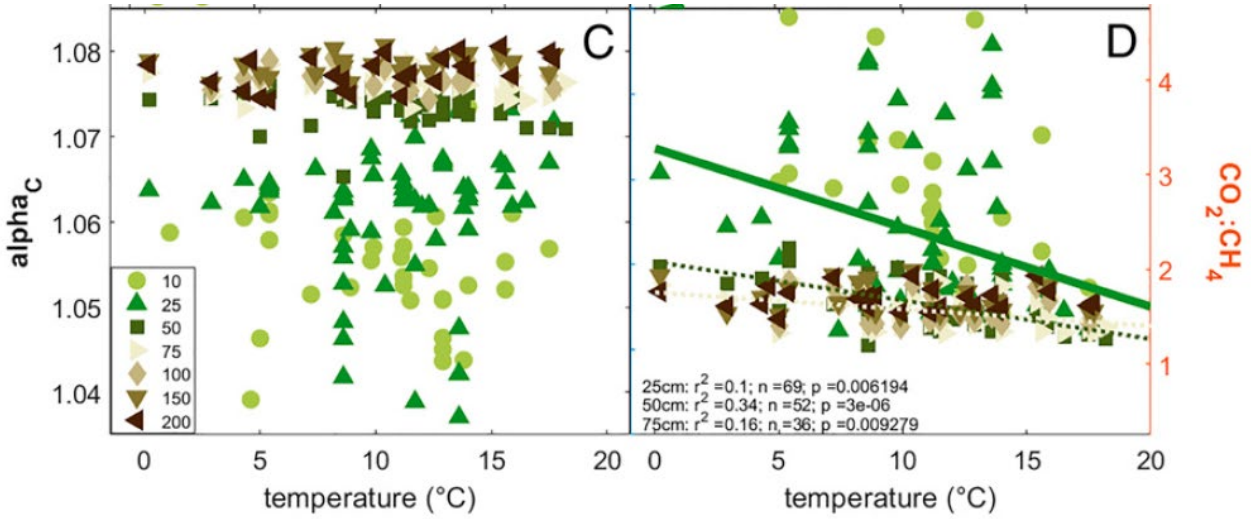
These allow us to take porewater samples from multiple depths within the peat profile.

We have been sampling profiles of porewater at SPRUCE since 2012 and pairing those with samples of the solid peat where appropriate.

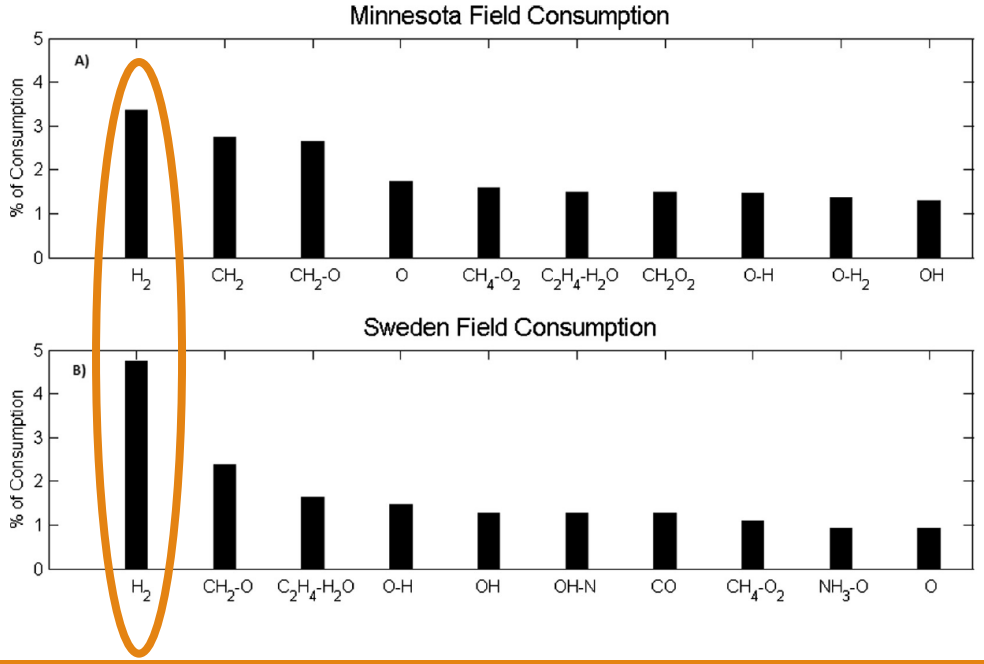


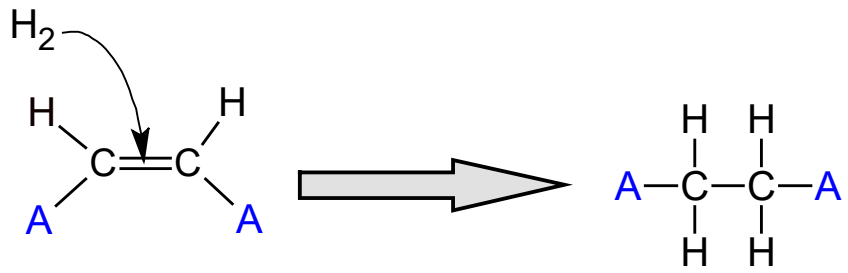
DIC and surface CH_4 correlated with warming. The strength of correlation is stronger in the <50 cm and weaker in the deep peat…

The CO_2:CH_4 ratio observed in bogs is frequently greater than 1.

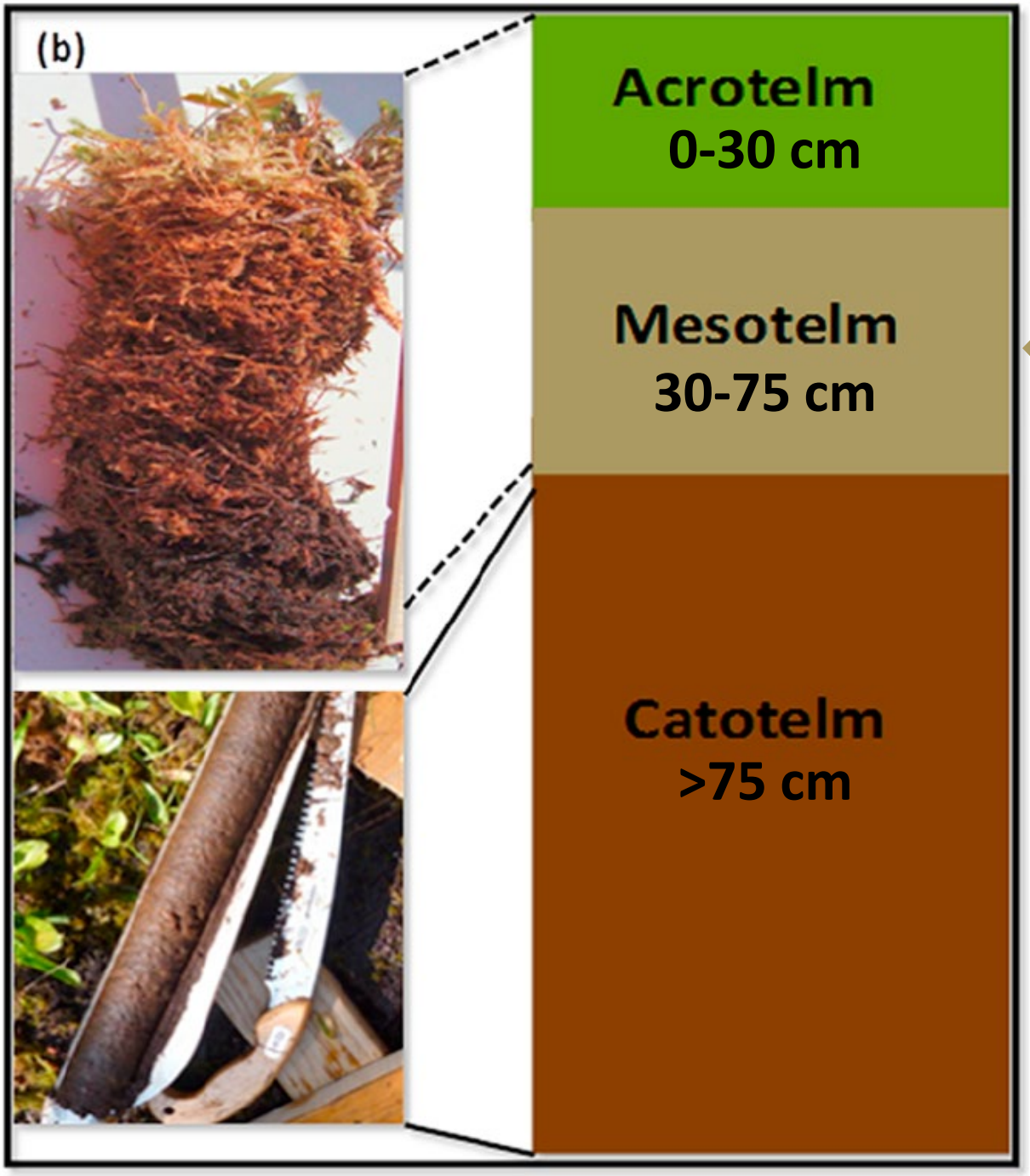


This is contrary to what we would expect based on electron balance and led us to hypothesize the hydrogenation mechanism of peat decomposition for which we found evidence both at SPRUCE and at Stordalen





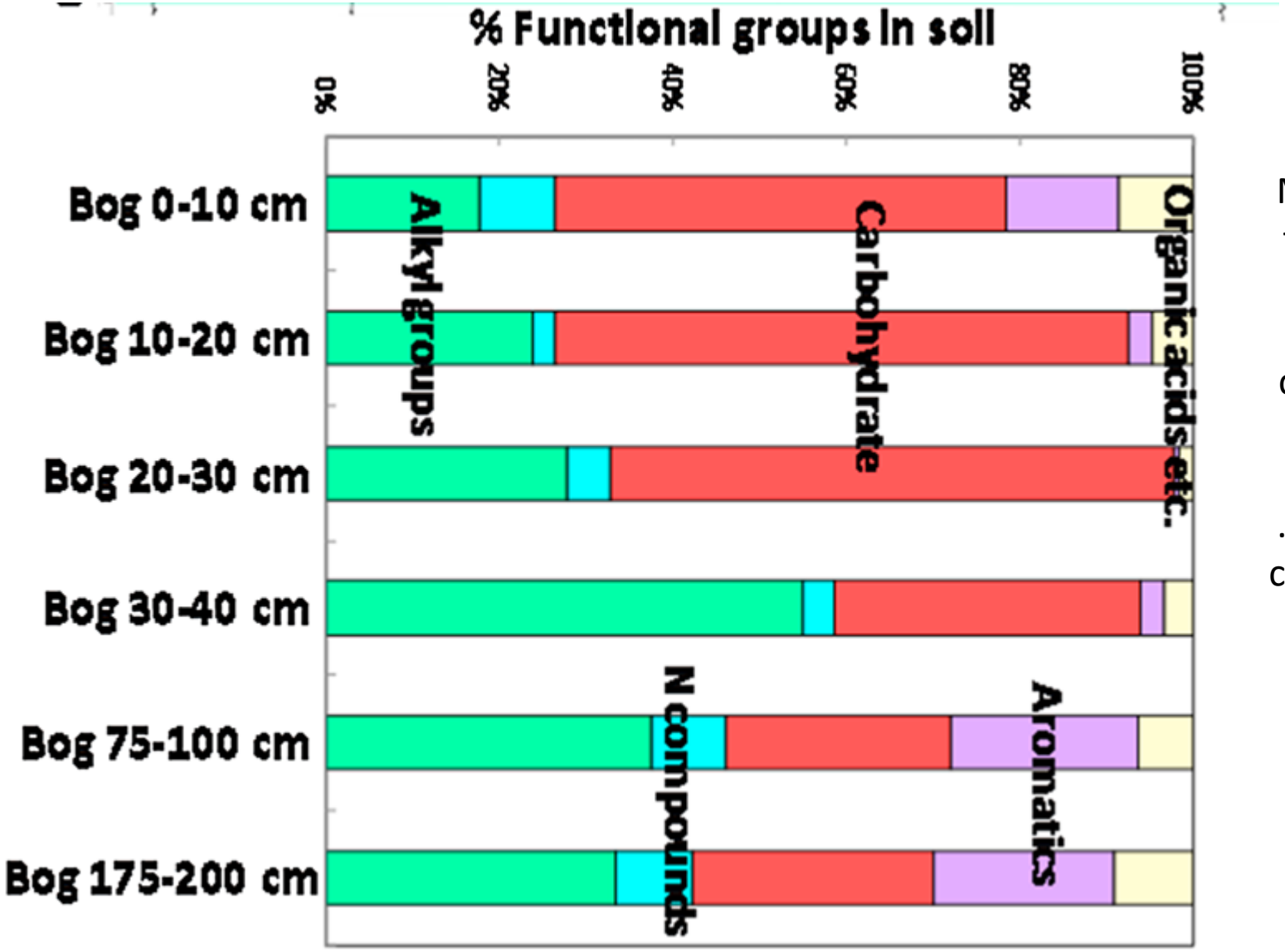
This is a way to use excess hydrogen in the environment from CO_2 production without needing to make CH_4 in a sustained way.



Area where water table fluctuates

Early on we, led by Malak Tfaily, identified this as an area of high microbial activity suggesting this zone is important to CO_2 and CH_4 production.

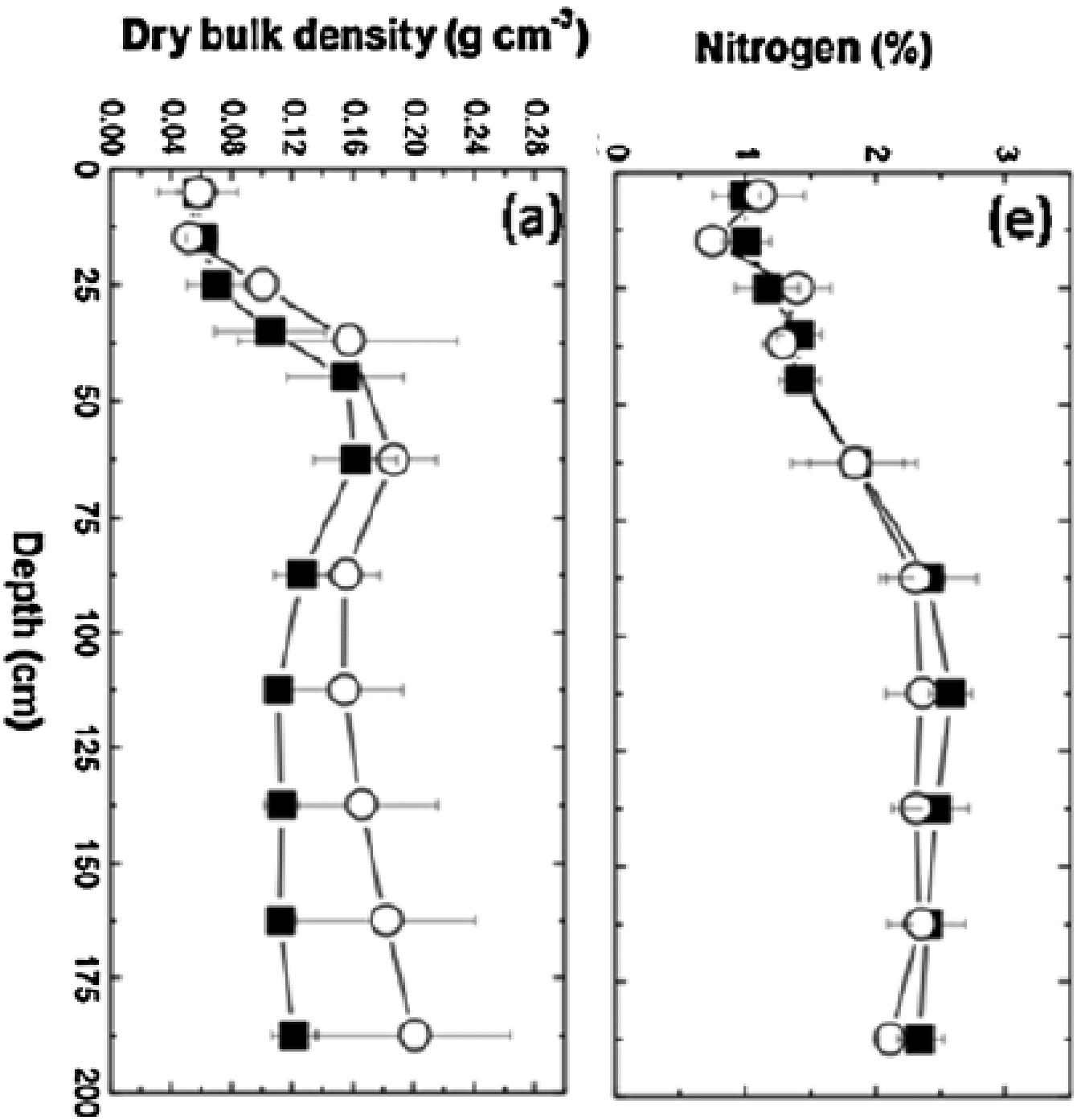
S1 Bog peat



Functional groups by quantitative NMR

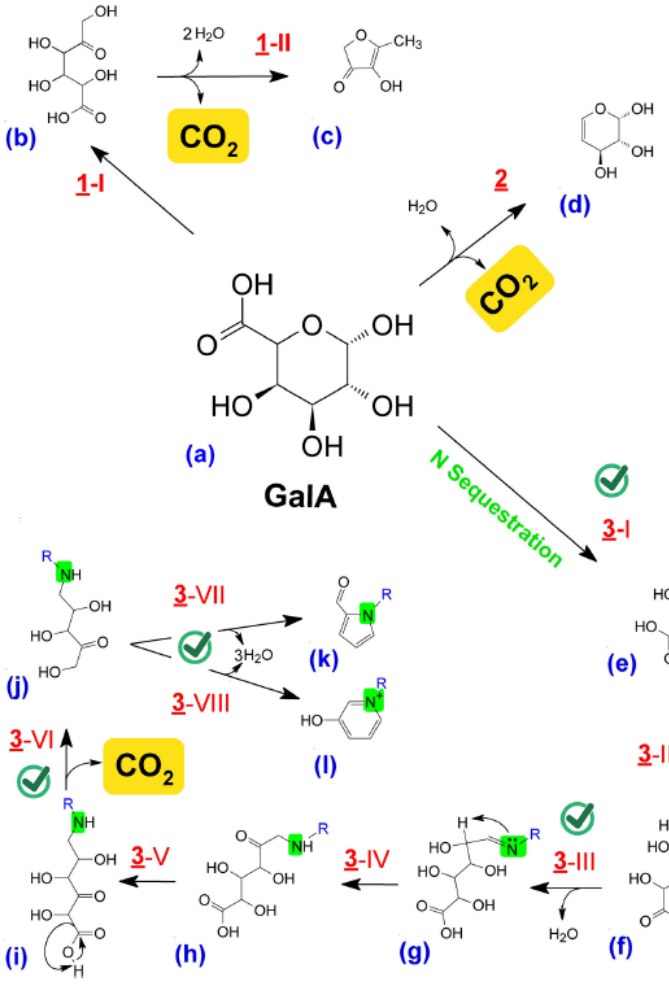
Malak observed in this zone a strong decline in carbohydrate content of peat @ mesotelm

…and increasing N content of the peat

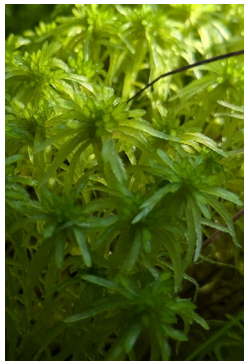


%N of peat is increasing with depth—consistent with incorporation of N into the peat during decomposition.

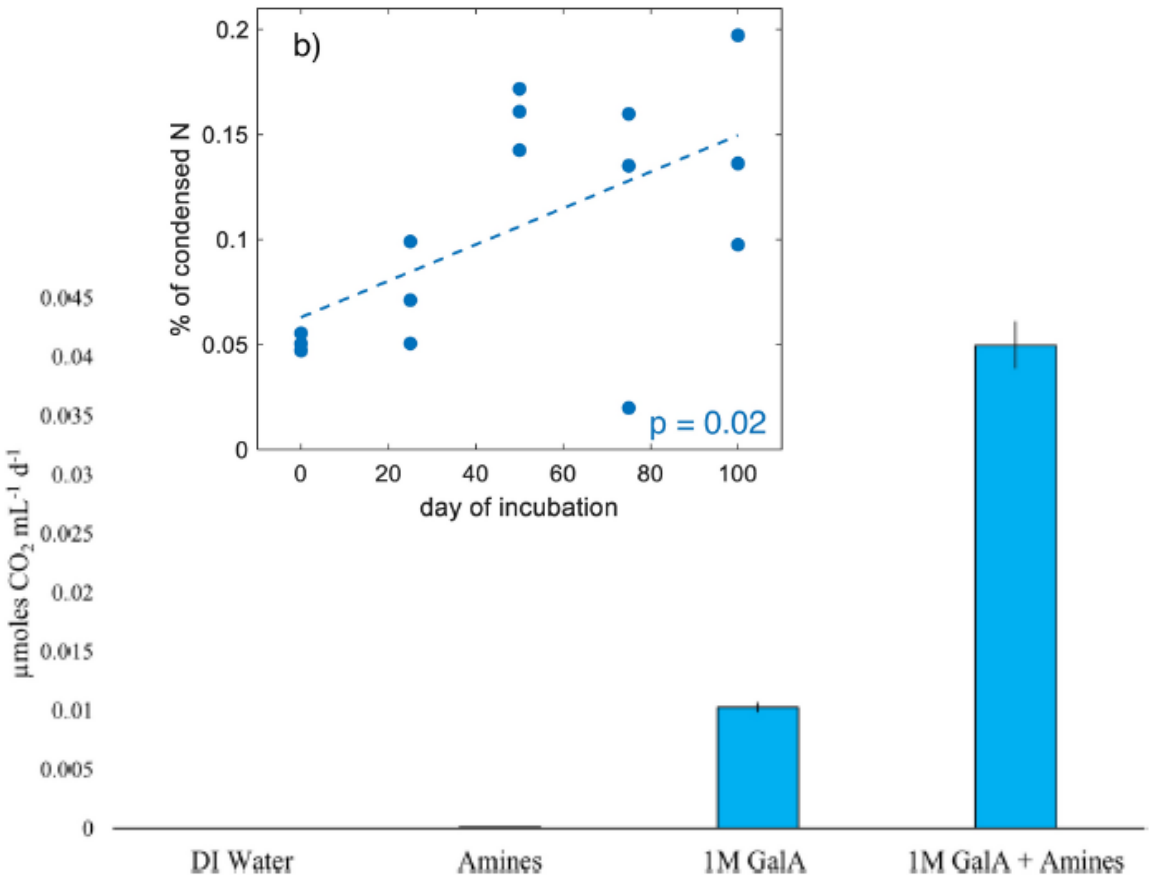
This observation could also help explain the sustained high CO_2:CH_4 ratios in bogs, but in another way…



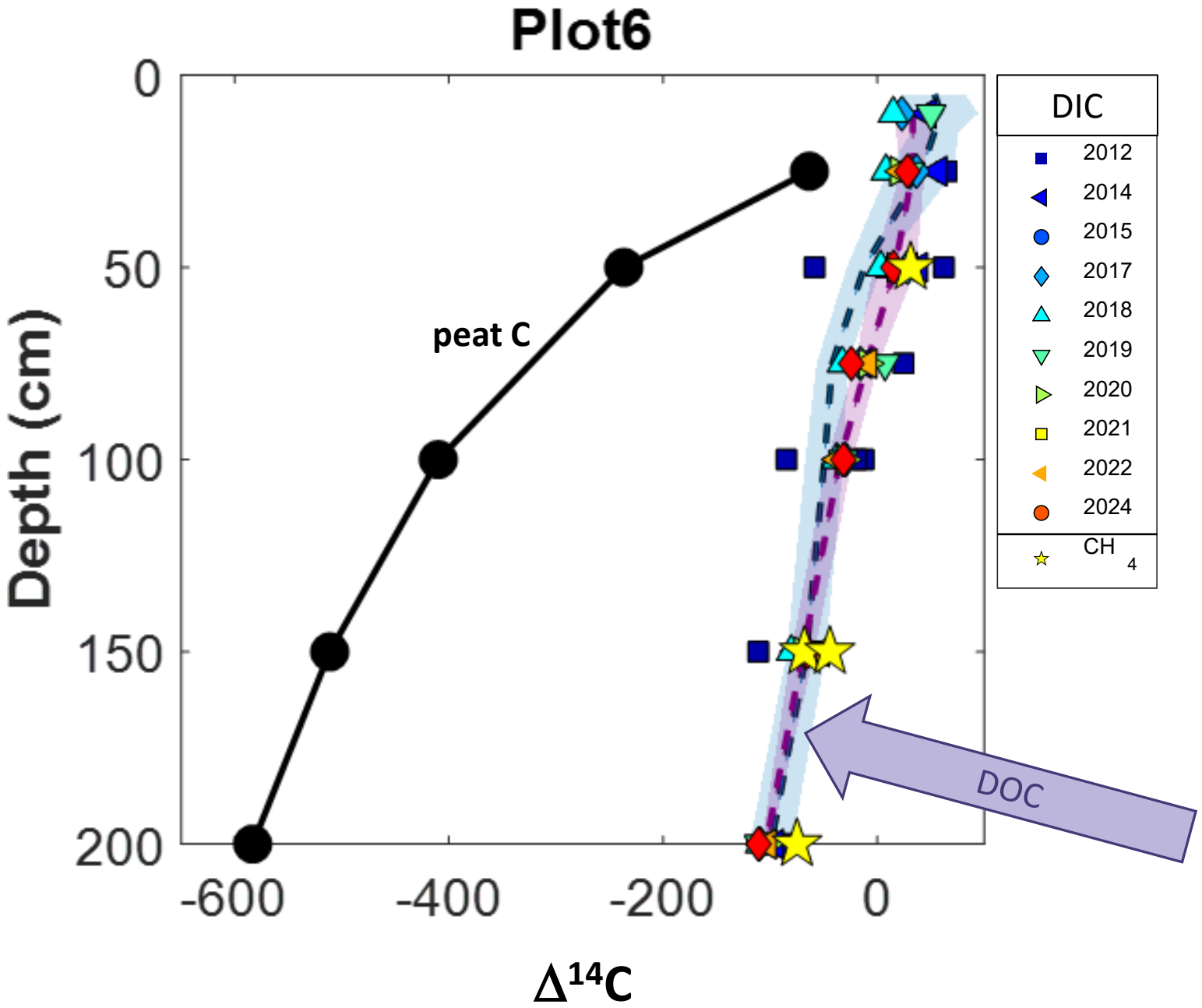
Galacturonic acid—produced abundantly by Sphagnum—an react with amines to create highly condensed N-containing structures. During this process CO_2 is expelled via abiotic decarboxylation processes. Suggesting a possible contribution of abiotic CO_2 in the C cycle.

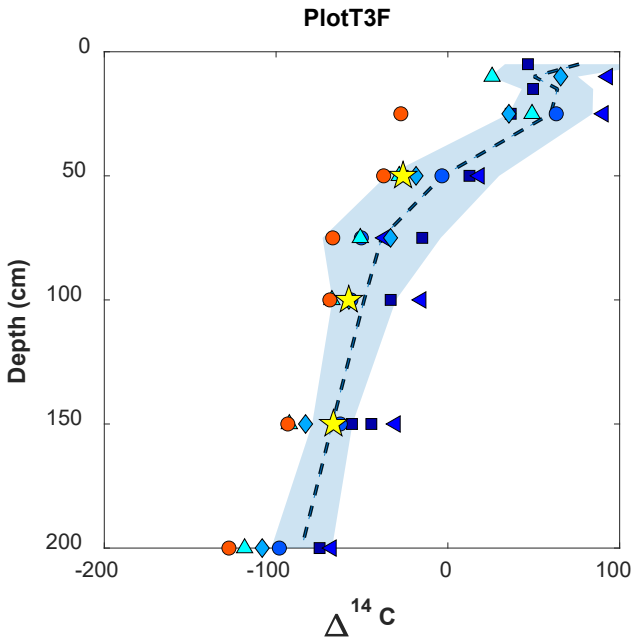


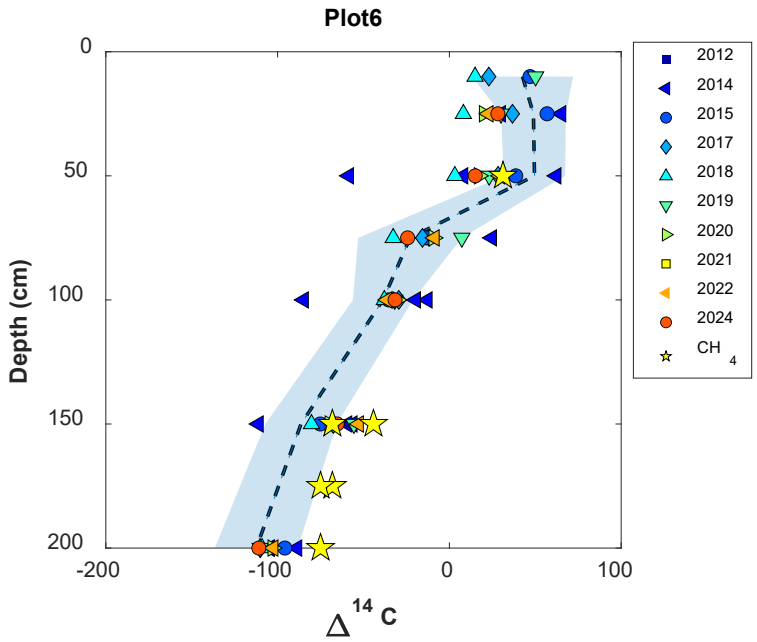
up to 13% of CO_2 production in Stordalen peat was abiotic

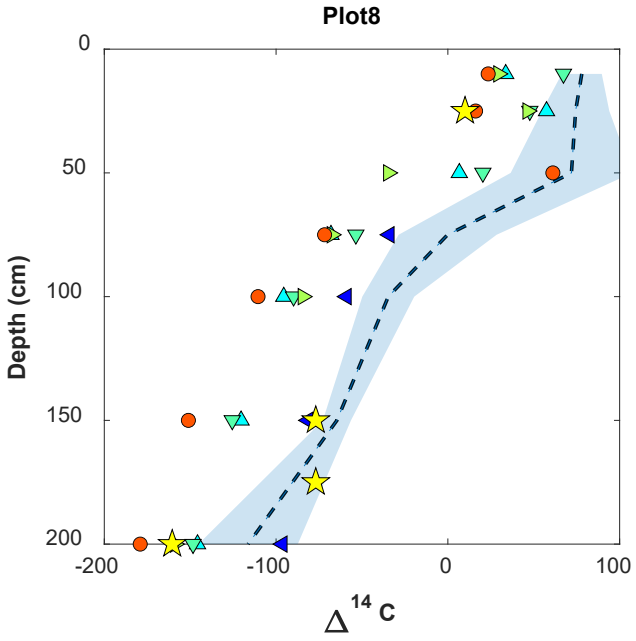


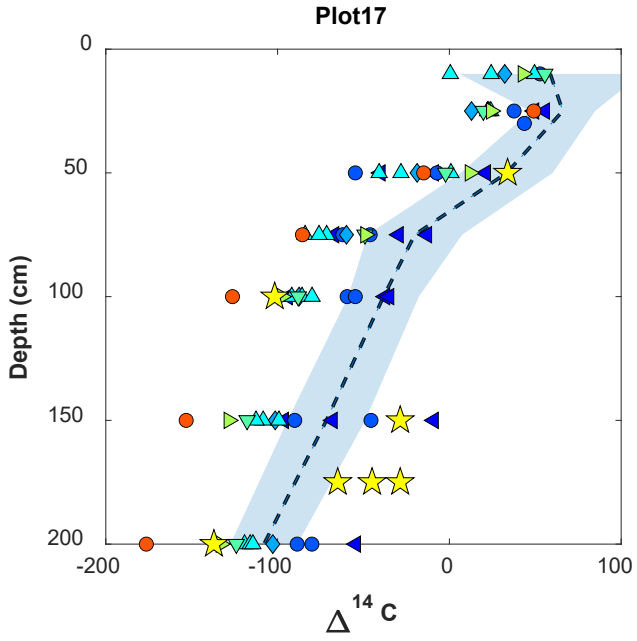
Controls on biotic C gas production


Plot6
Depth (cm)
0
50
100
150
200
-600
-400
-200
0
Δ14C
peat C
DOC
DIC
2012
2014
2015
2017
2018
2019
2020
2021
2022
2024
CH4





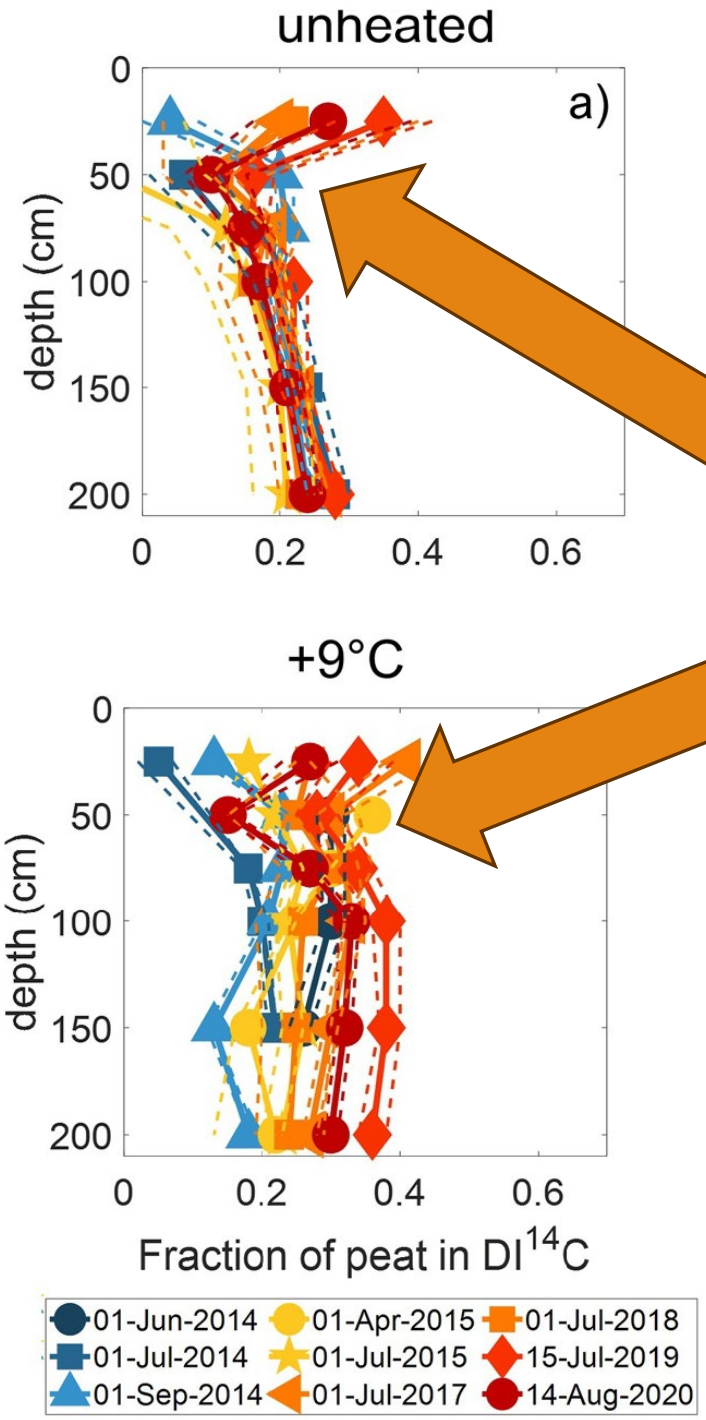




CH_4 and CO_2 production is dominated by dissolved organic carbon

Over time the respiration products (DIC), are increasingly influenced by peat in the warm plots.

Shaded area is the DO^{14}C. Stars are methane.



The contribution of peat C to DIC was minimum at 50 cm where activity is presumed to be the highest

…and increased in the deepest peat

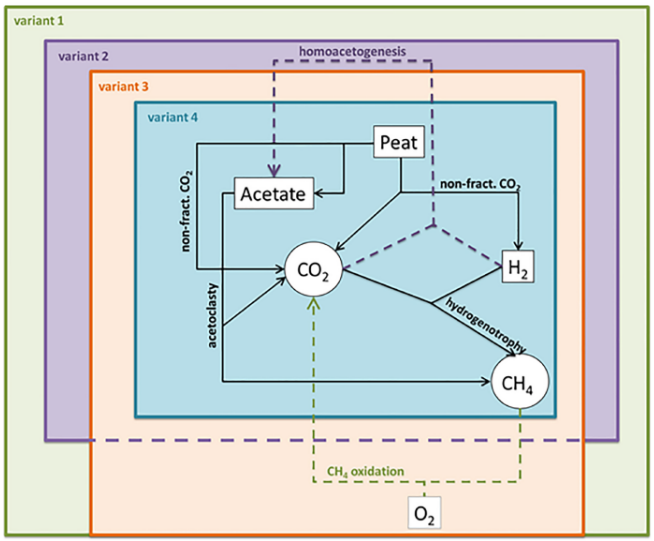


FIGURE 2 | Schematic overview of model variants showing included reaction pathways in each variant. Neumann et al's. (2016) fugitive methane term was not included in any model variant because the closed incubations should not have allowed gasses to escape the system. Variant 1 is the most inclusive, incorporating all reactions, variant 2 excludes CH_4 oxidation, variant 3 includes CH_4 oxidation, but excludes homoacetogenesis, and variant 4 excludes both CH_4 oxidation and homoacetogenesis.

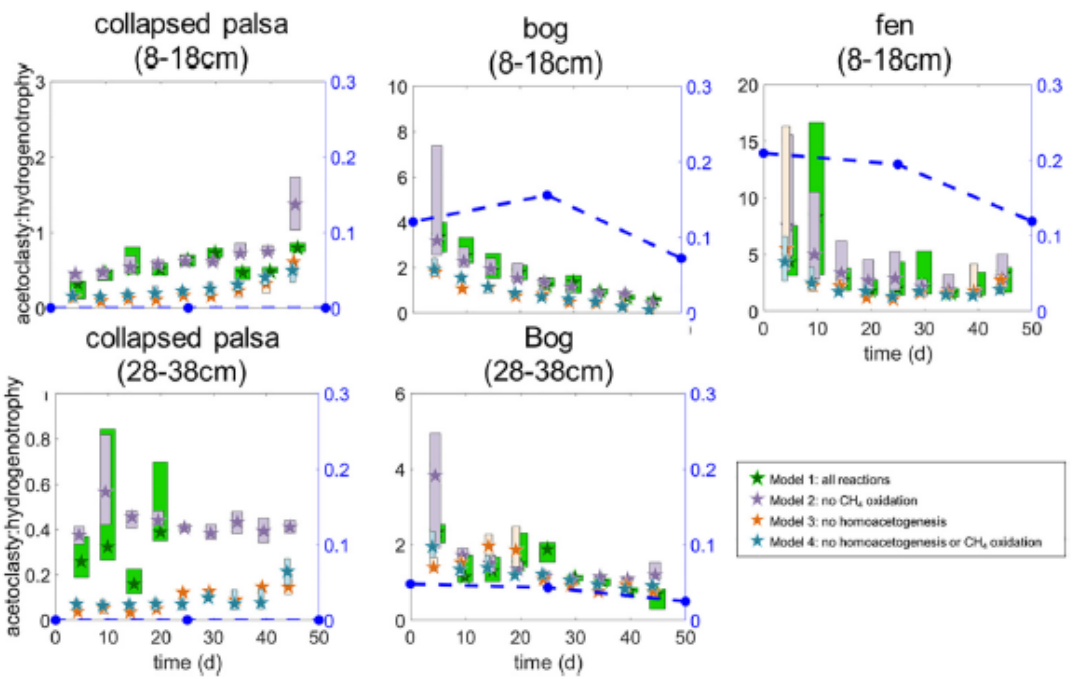
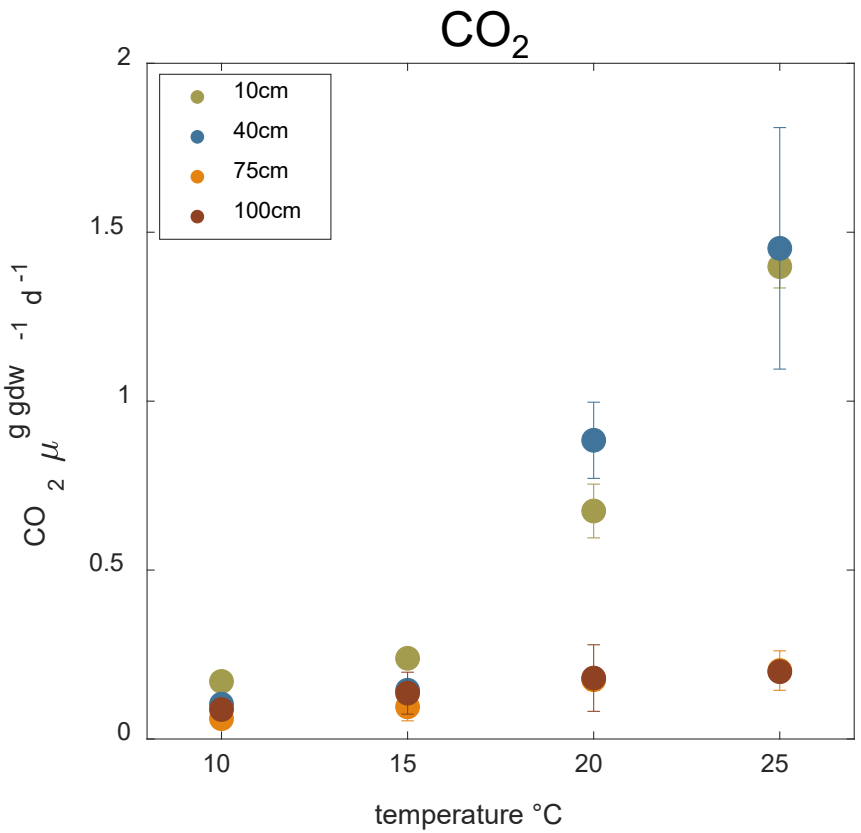
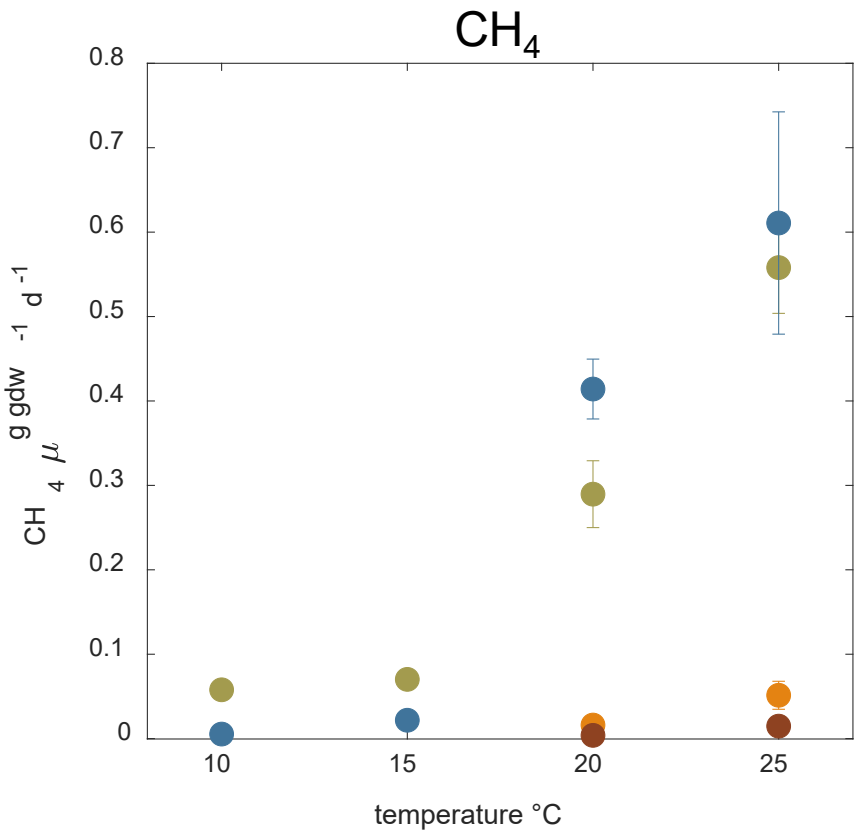


FIGURE 5 | Ratio of modeled rates of acetoclasty:hydrogenotrophic methanogenesis for each of the four model variants. Stars indicate medians and box heights outline interquartile ranges of posterior likelihoods. Box widths are staggered so that overlapping ranges can be visually distinguished. Blue symbols with dashed lines indicate the ratio of acetoclast to hydrogenotroph abundances in the incubations. In the collapsed palsa (28–38 cm) the hydrogenotrophy rate at days 25 and 30 was 0 μmol $month^{-1}$ (i.e., acetoclasty:hydrogenotrophy was undefined) which prevented us from calculating ratios after day 20 for that incubation.

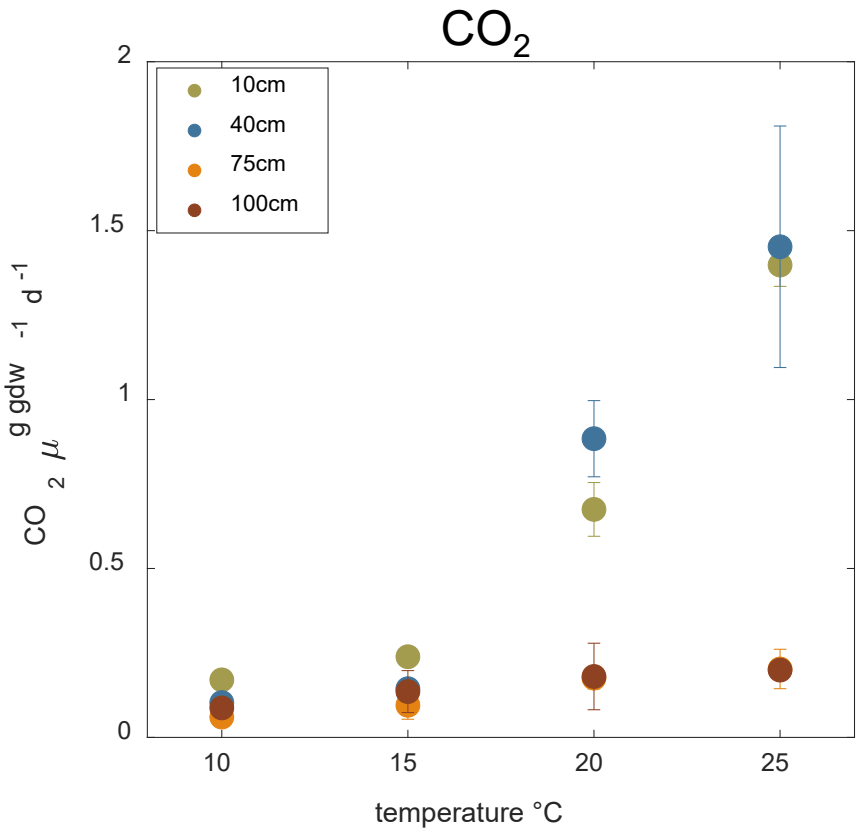
Measuring CO2 and CH4 production potential in peat incubations (SPRUCE).

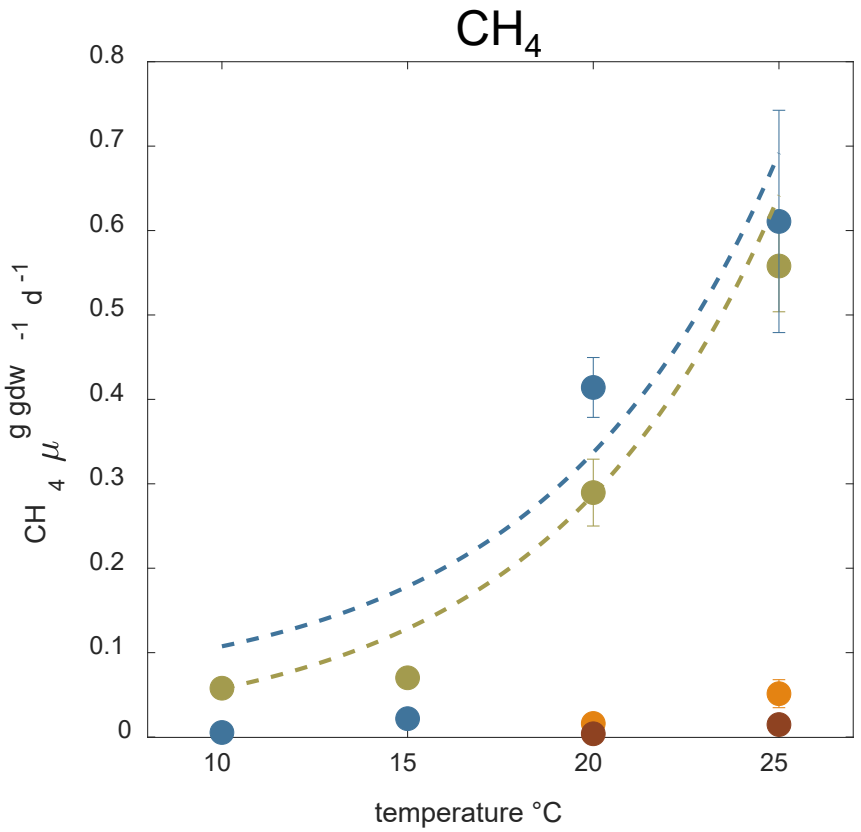
Production rates at 10cm and 40cm are similar, but at 75 cm and below they are near zero suggesting that the “active zone” does not encompass the 75 cm depth. Most of the production is occurring shallower than 75 cm.





In incubations of peat, CO_2 and CH_4 production declines >=75cm

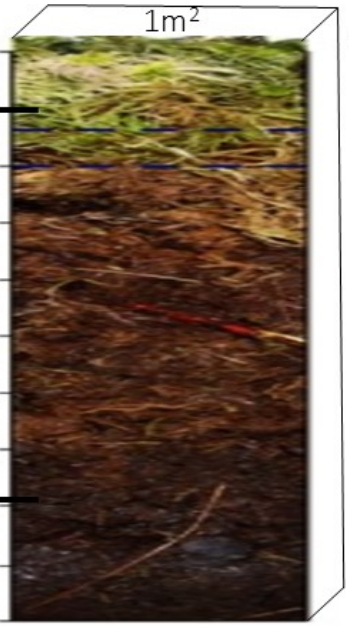




We fit a line to estimate the temperature response for each depth.

In Stordalen we were able incorporate such rates measured from incubations with environmental parameters to estimate emissions and found reasonably good agreement between the measured values and the estimates over the last decade of emission data.

Modeling Methane Flux

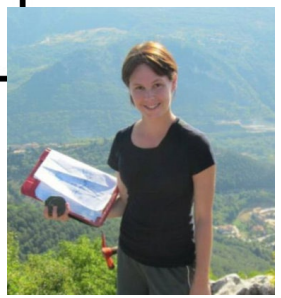


(1) Identify depth range contributing to methane production

(2) For every 1-cm increment of this depth range, estimate methane production rate using..
- (a) soil temperature
- (b) formula relating temperature to methane production rate

(3) Sum estimated values from each 1-cm increment

(4) Repeat these steps for every day over a seven-year period.



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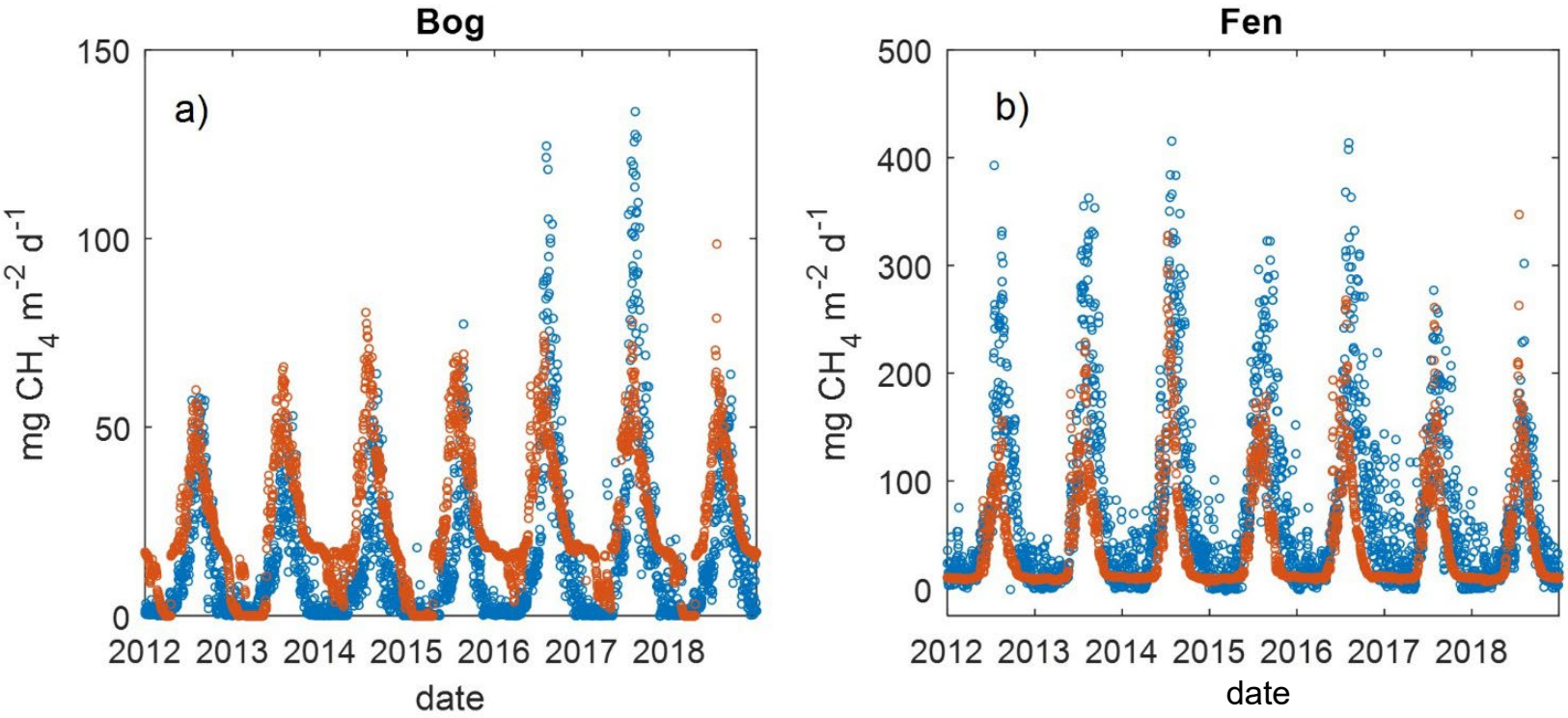
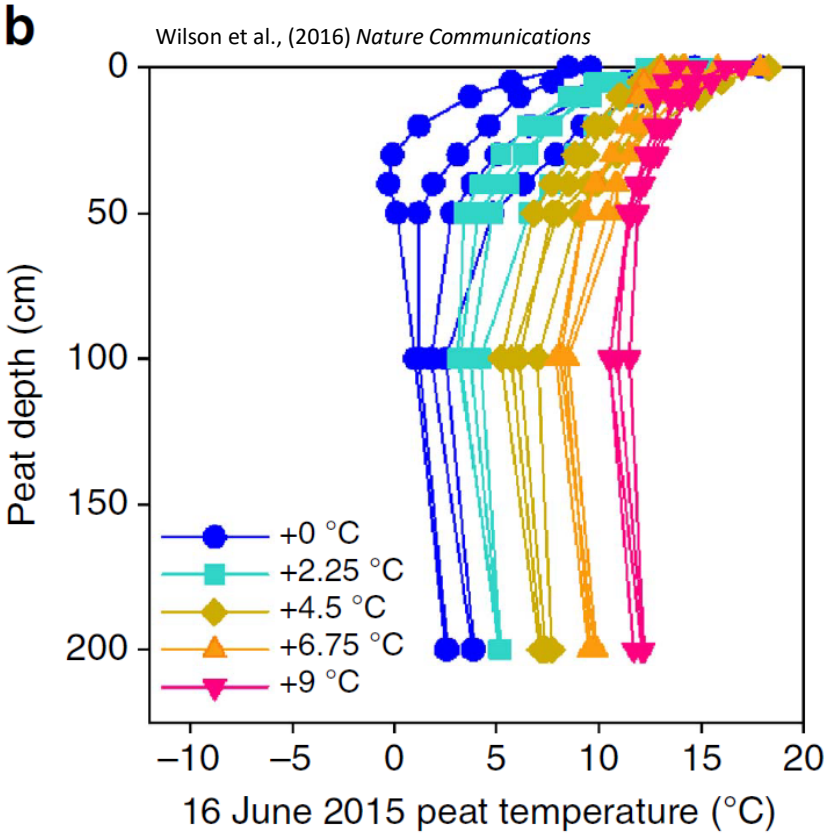
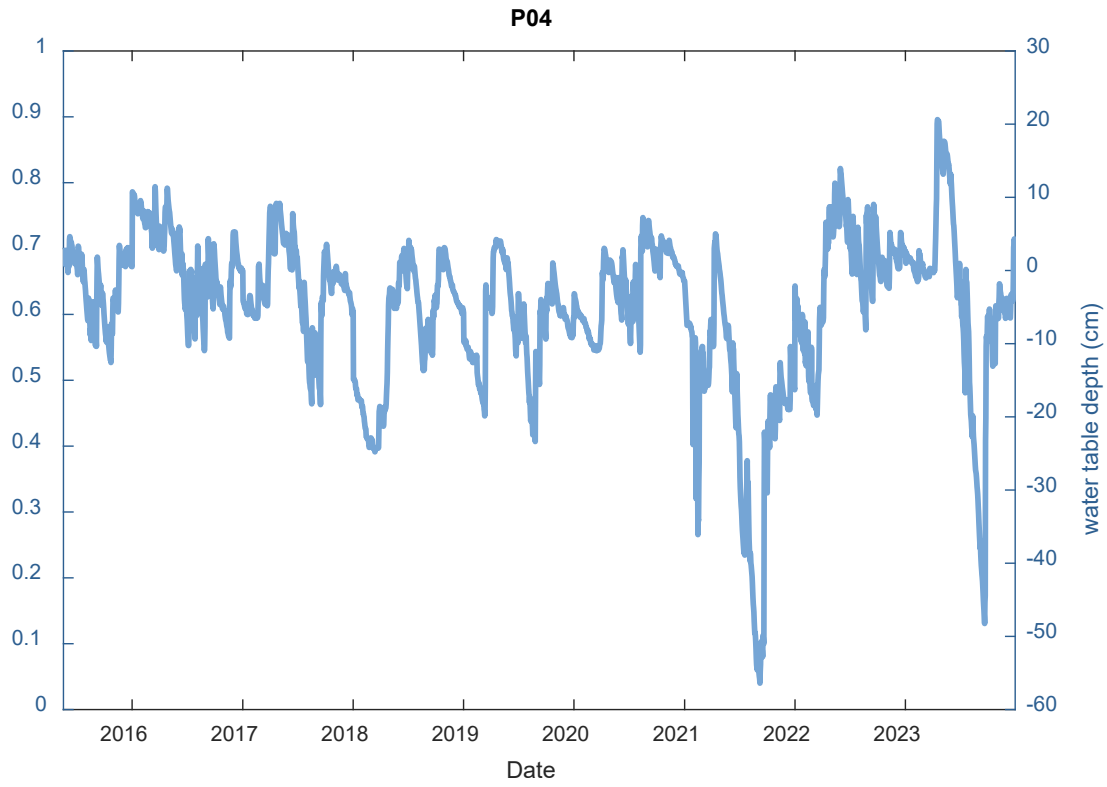
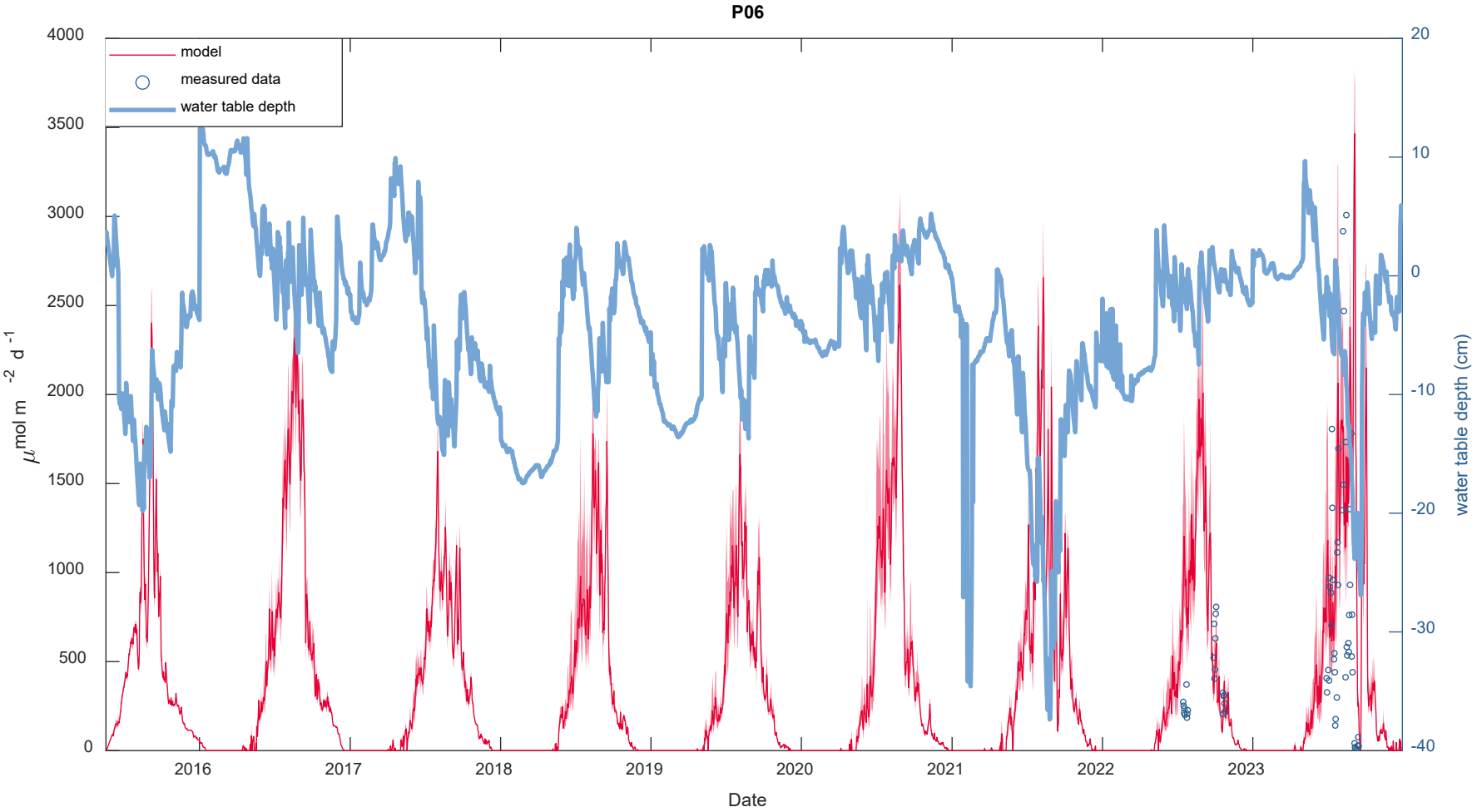


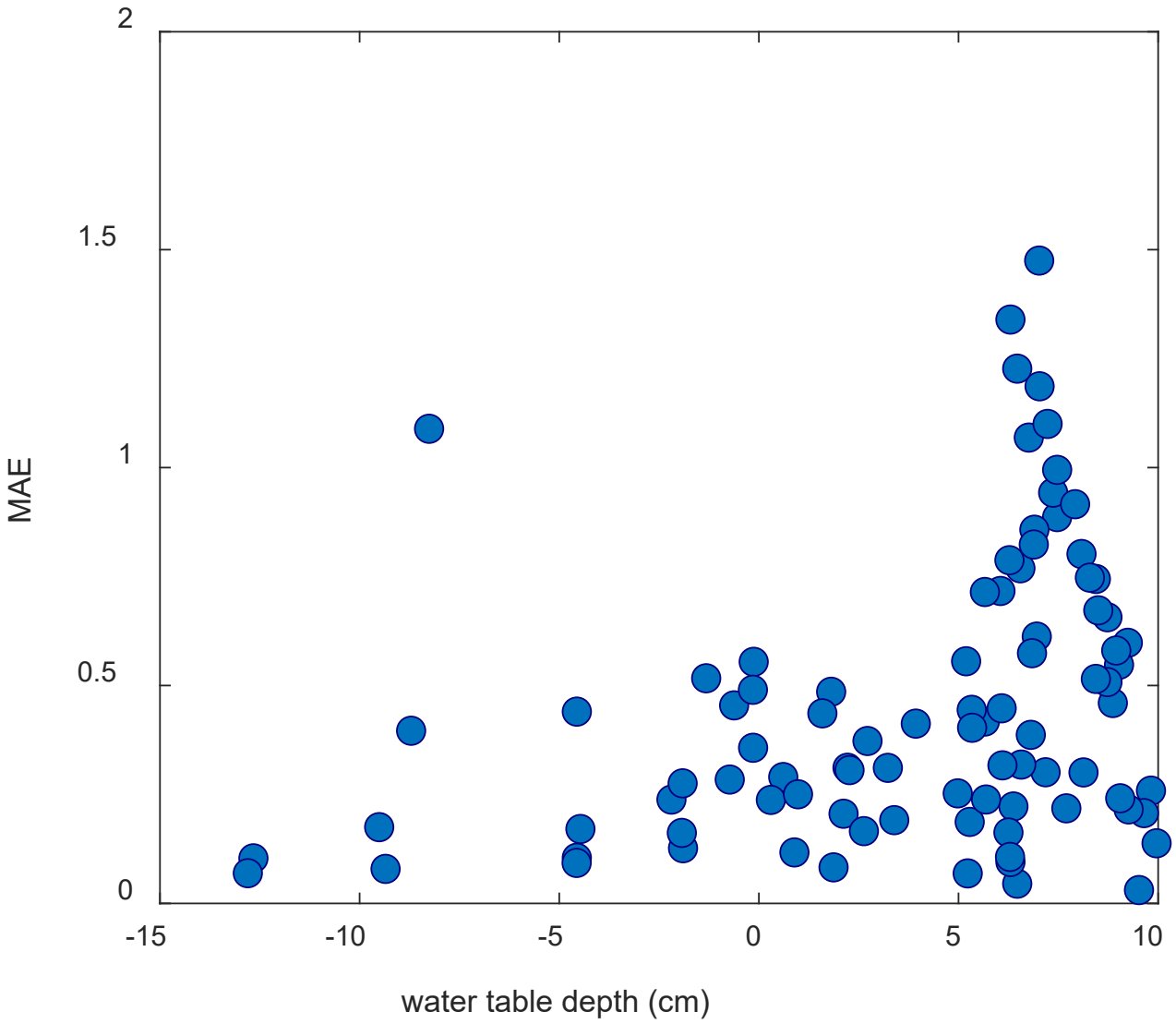
We used a similar approach here at SPRUCE combining with peat temperature profiles and water table depths.





Predict CH_4 emissions and compare to measured rates





Model predicts the measured results within a factor of ~1.5.

Summary:

We identified the top of the mesotelm (less than 75 cm) as the zone most consequential to CO_2 and CH_4 production.

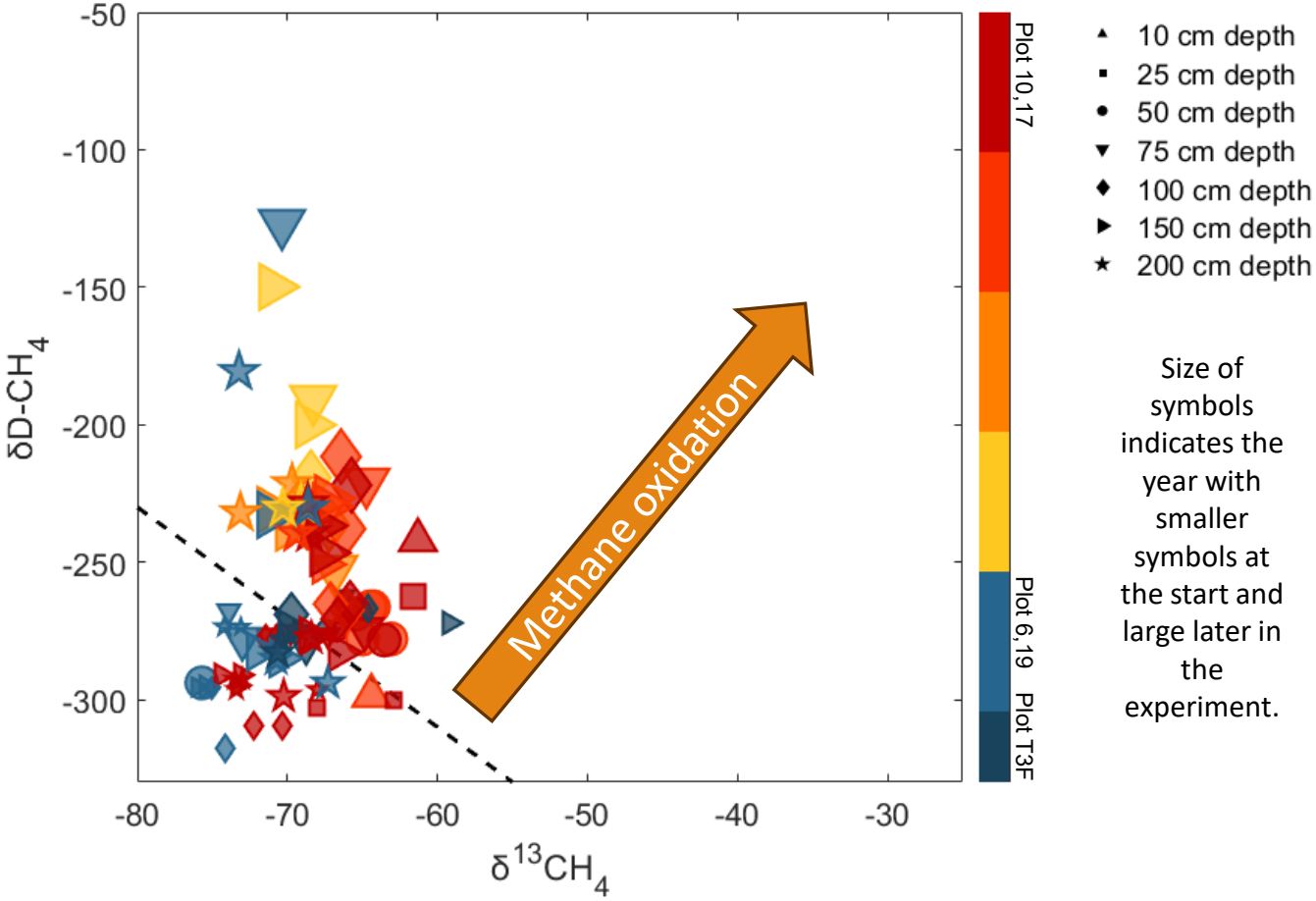
We identified two potential mechanisms, one of them abiotic, which could sustain CO_2 production without CH_4 thereby helping to explain anomalously high CO_2:CH_4 ratios observed in peat.

Radiocarbon evidence shows that dissolved organic carbon is the most important substrate for CO_2 and CH_4 production, but that with warming, peat C increasingly contributes.

Using ex situ incubation to measure CH_4 production potentials allows us to predict field methane emissions within a factor of 2 suggesting that temperature and water table depth are strong controls on emissions in the field.

These results were applicable to both SPRUCE bog and Stordalen in northern Sweden supporting the generalizability of our findings.

Extra Slides

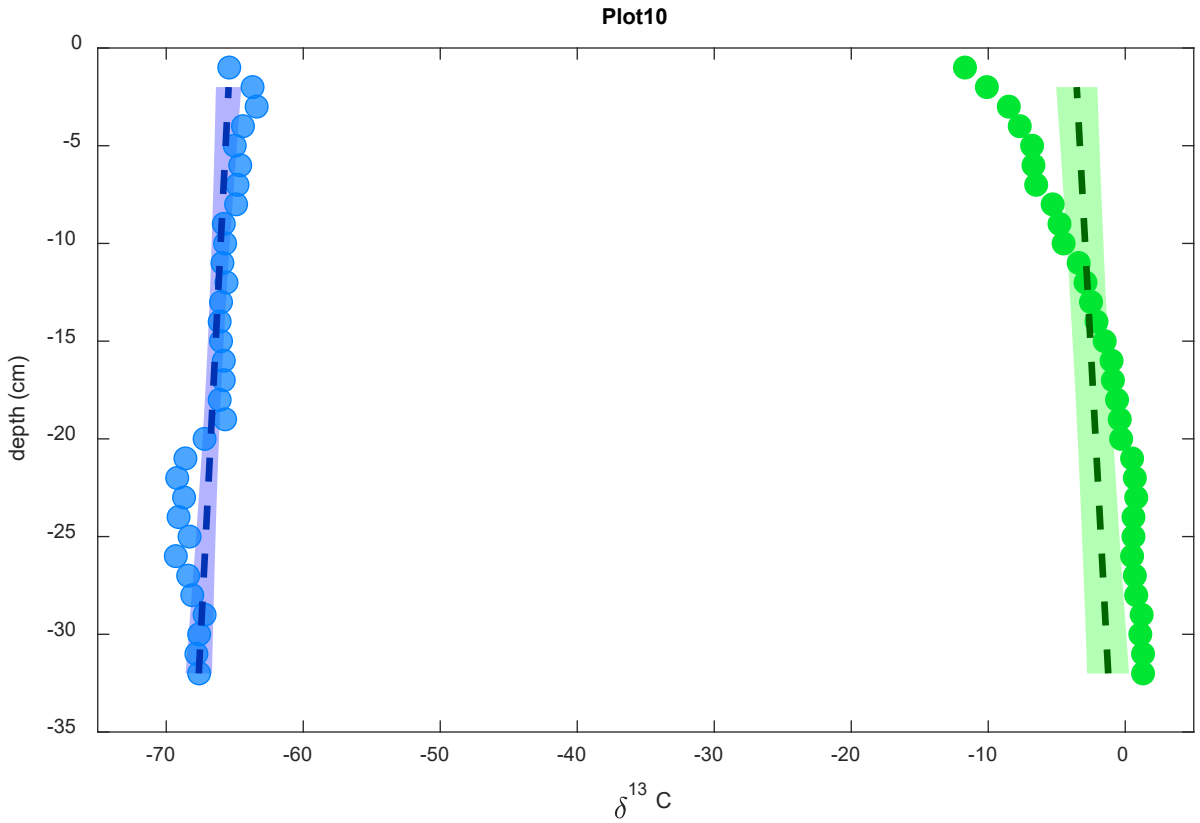


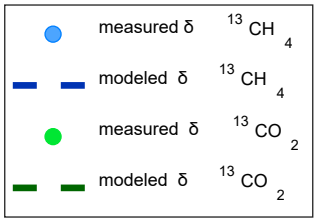
Size of symbols indicates the year with smaller symbols at the start and large later in the experiment.

…looking for evidence of methane oxidation

Deuterium isotopes not indicating much oxidation

Incidentally, the methane deuterium appears heavier over time, even in the unheated treatments. More evapotranspiration in all plots? Could this be related to the source gas for the heating?





Attempting to fit high- resolution depth profiles of $\delta^{13}CH_4$ and $\delta^{13}CO_2$ simultaneously, to find fraction of CH_4 that has been oxidized.

…again little isotopic evidence of methane oxidation