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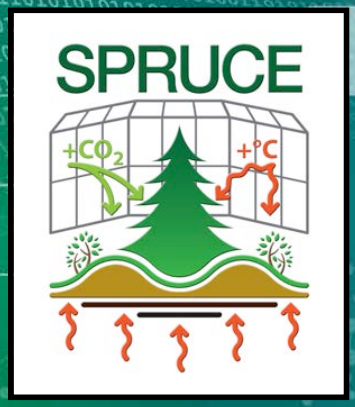
Drought-induced reductions in net methane emissions from an ombrotrophic peatland are enhanced across a range of experimental warming treatments

4 May 2020

Hanson PJ, Phillips JR, Iversen CM, Ricciuto DM, Yuan F, Zhang J, Xu X

E-mail: hansonpj@ornl.gov



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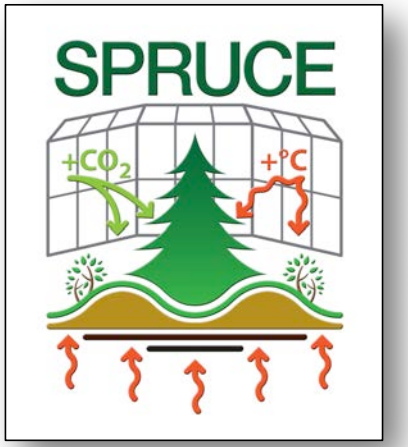
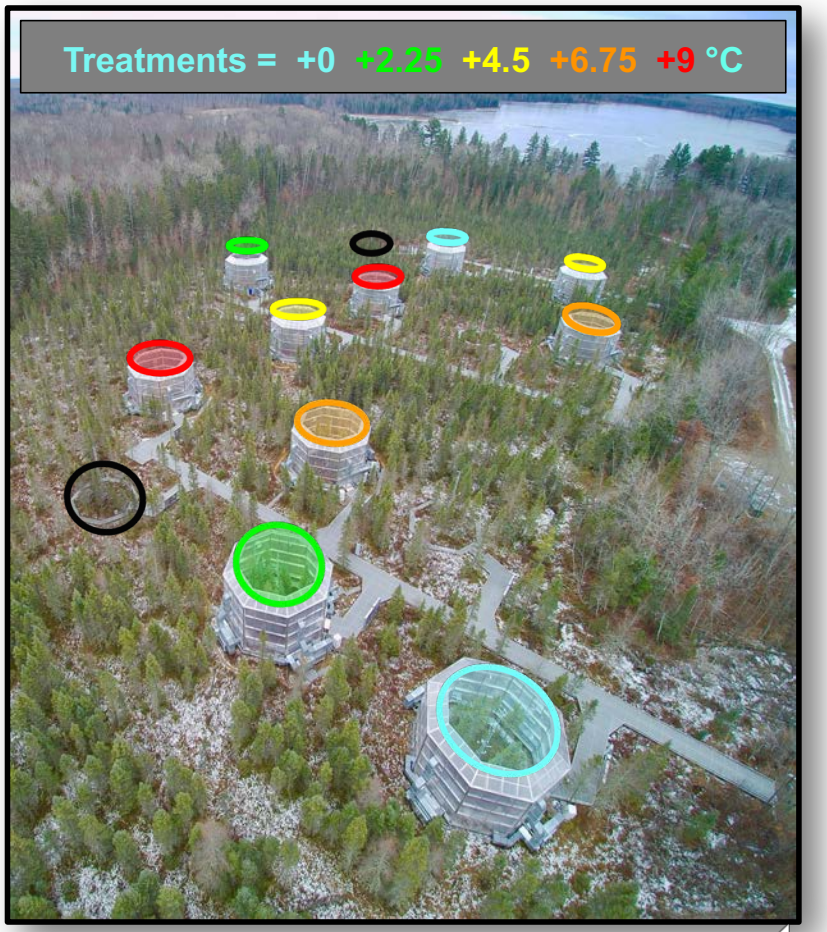
U.S. DEPARTMENT OF ENERGY

Spruce and Peatland Responses Under Changing Environments



An experiment to assess the response of northern-peatland, **high-carbon** ecosystems to whole-ecosystem warming and exposures to elevated atmospheric CO_2 concentrations.



- Funded by the US Dept. of Energy's Biological and Environmental Research Program within the Office of Science.
- A cooperative venture between ORNL and the USDA Forest Service with interested university cooperators.

Will future warming release 10,000 years of accumulated carbon from peatlands that store 1/3 of the earth's terrestrial carbon? At what rate, and in what forms?

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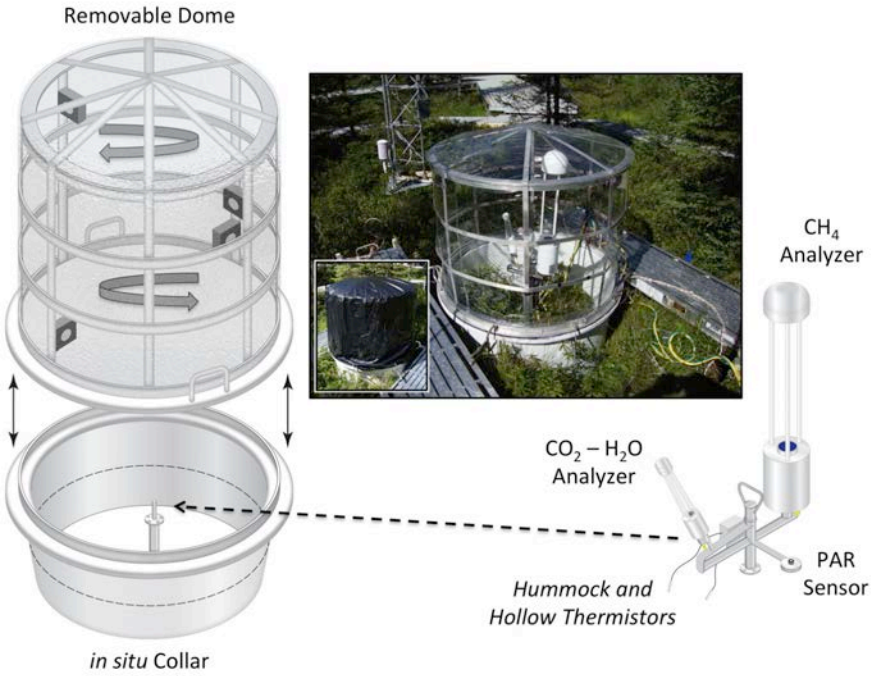
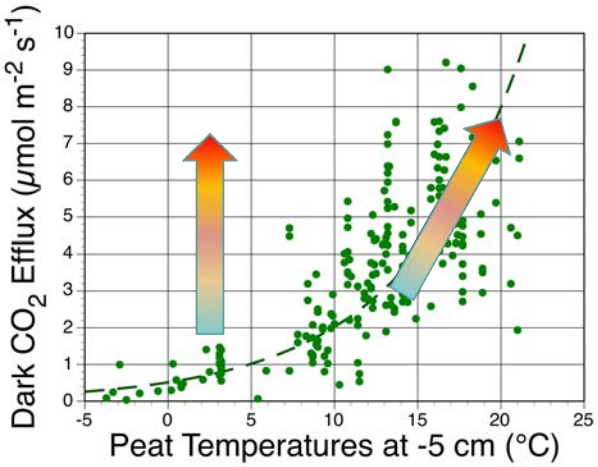
Community-level Assessments net CO_2 and CH_4 Efflux

Team: P. Hanson, J. Phillips, et al.



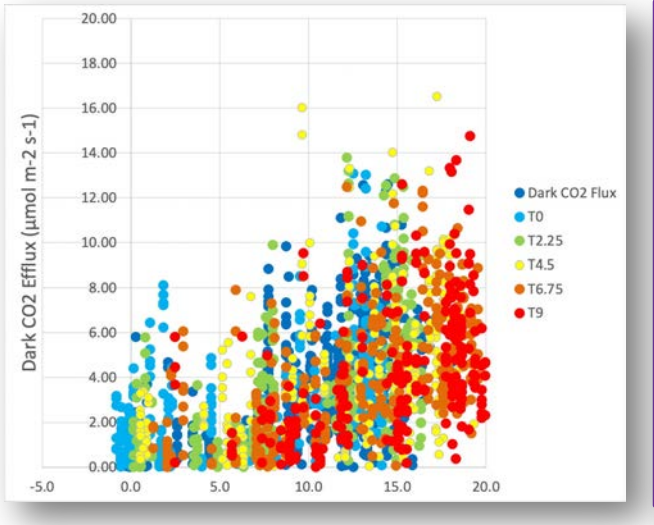
Hanson et al. (2016)
Biogeochemistry 129:255–272

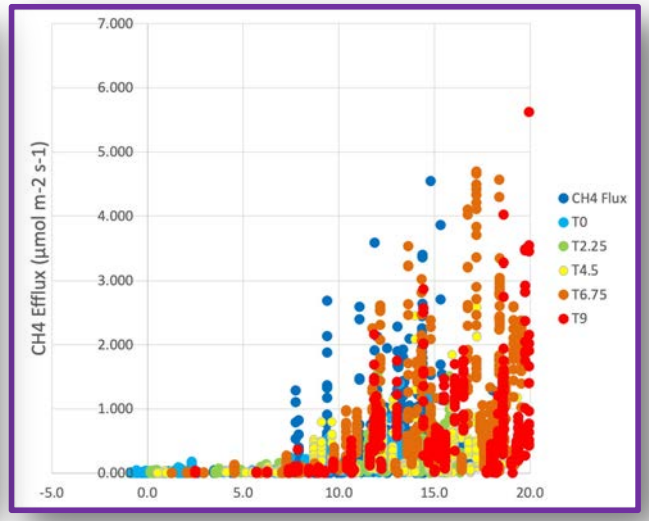
Hypothesized Responses

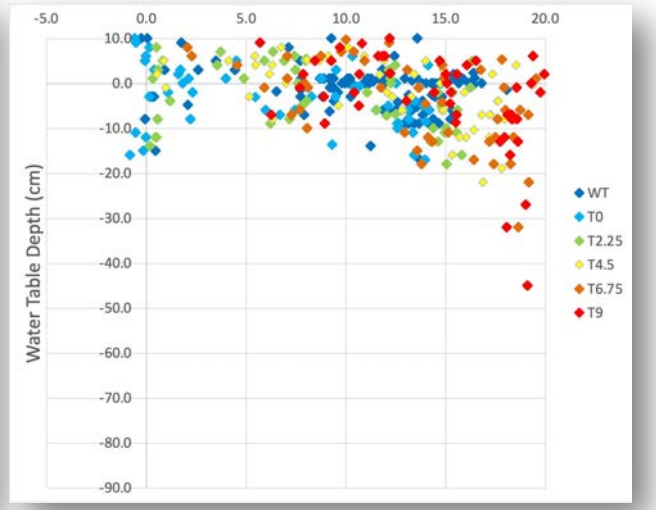


- Temperature would increase efflux of both gases due to an enhancement of base activity or through extended time at high temperatures.
- eCO_2 was expected to enhance net CO_2 and CH_4 efflux through increased substrate supply and base activity.

CO_2 and CH_4 Flux Under "Normal Wet" Conditions







- Under consistently wet conditions the CO_2 and CH_4 efflux from the bog can be interpolated from linear (CO_2) or exponential (CH_4) conditions.
- After 4-years of treatments CH_4 fluxes in the warmest treatment have approached those of CO_2 in "wet" years.

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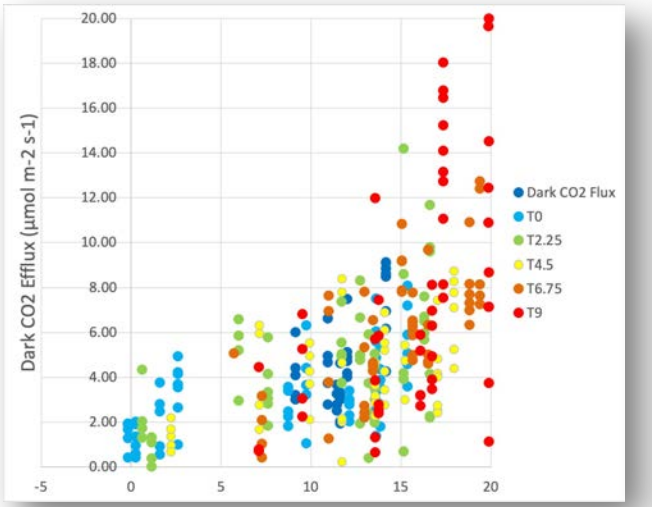
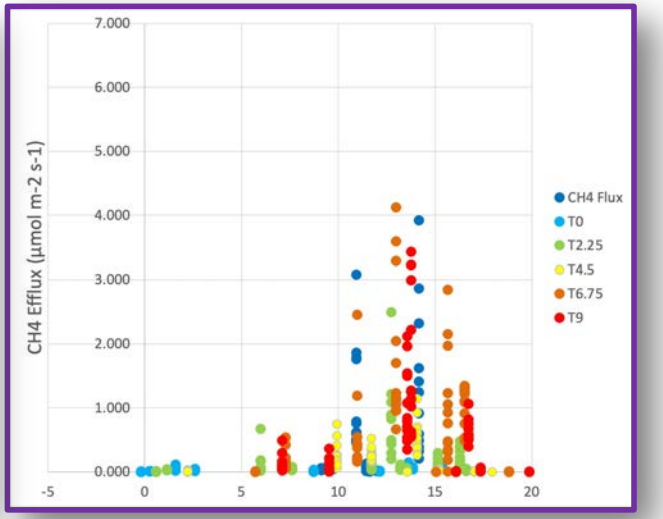
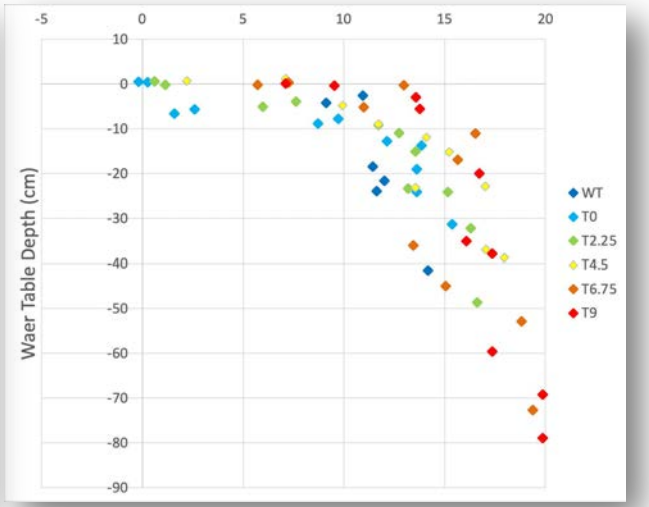
CO_2 and CH_4 Flux Under 2021 "Drought" Conditions



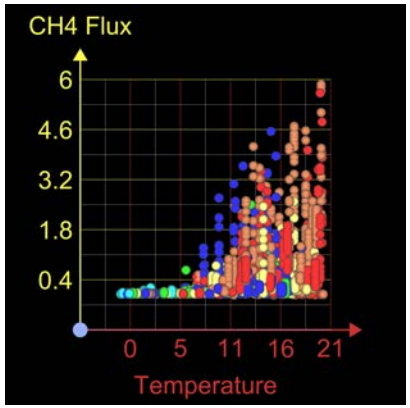


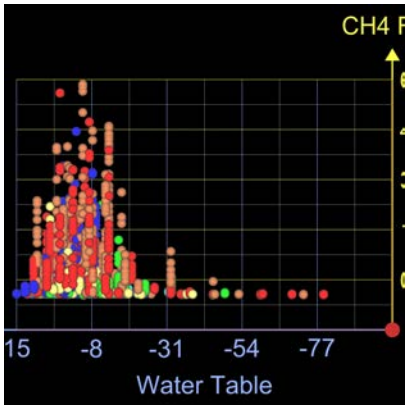


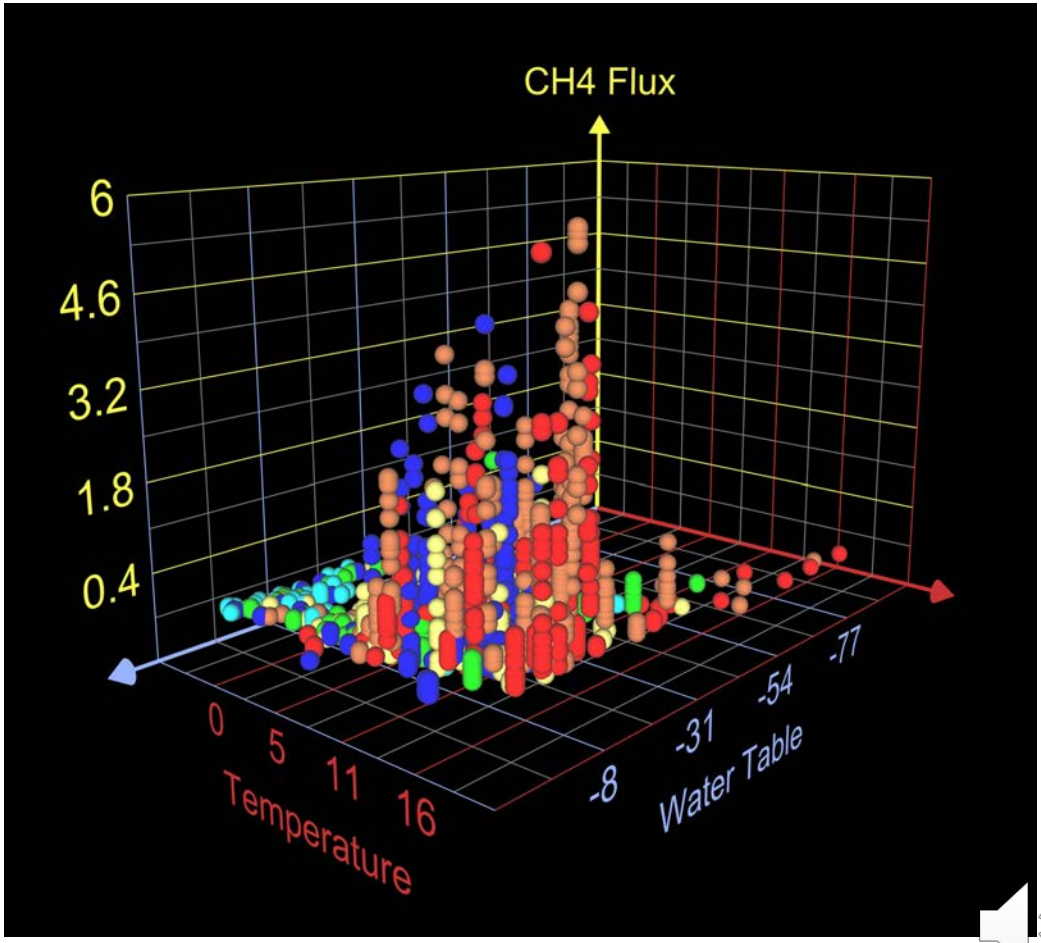
- During the 2021 drought year water table levels dropped with drought and showed the most change in the warmest treatments.
- Under the warm dry conditions net CO_2 efflux was enhanced with warming exhibiting a stronger exponential response, but net CH_4 flux was reduced if not shut off at the depth of the 2021 drought.

3D View of all CH_4 Flux Data – 2016 to 2021

- All CH_4 flux data by treatment showing exponential increases with warming, but truncation of flux at water table depths below -30 cm.







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We Modified Typical CH_4 Efflux Empirical Equations To Allow Interpolation of Annual Flux

Simple Exponential Equations applied to prior analyses (Hanson et al. 2020; Hopple et al. 2020, Wilson et al. 2021):

$$Efflux\ CH_4 = Base_{10°C} \times Q^{((Tx\ -\ 10)/10)}$$

The equations will need a modifier to account for drying/oxygenation to cover the transition associated with the loss of methane contributions under severe drying:

$$Efflux\ CH_4 = Base_{10°C} \times Q^{((Tx\ -\ 10)/10)}$$

$$Base_{10°C} = BaseOpt_{10°C} \times \boldsymbol{WT_{frac}}$$

WT_{frac} = f[Water Table Depth]

- *Inactivation of methanogens*
- *Activation of methanotrophs*
- *Possible loss of substrate due to reduced photosynthesis*

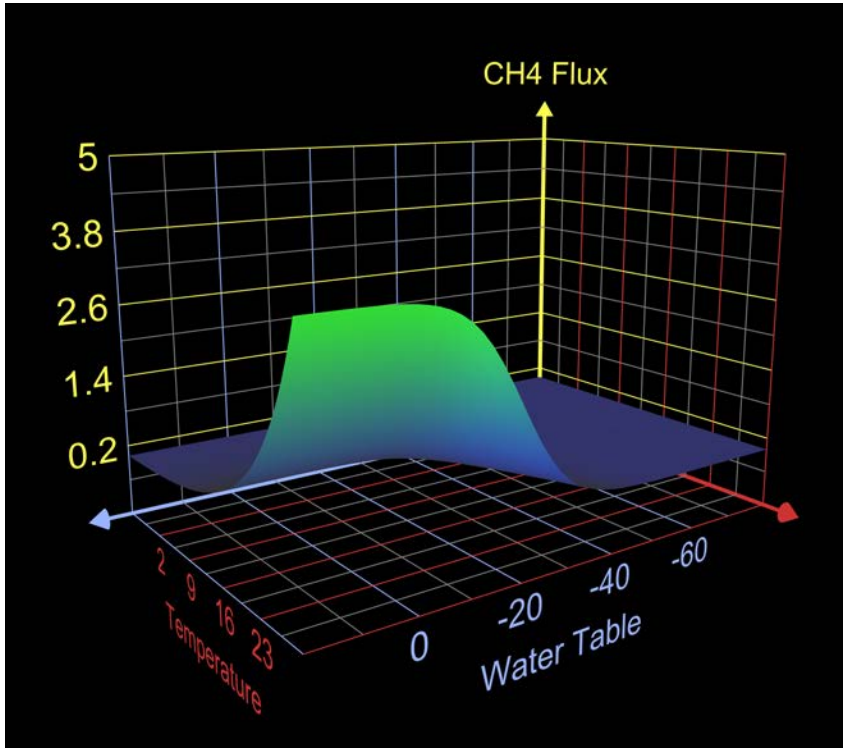
Capturing the Impact of Water Table Changes

An inverse sigmoid function works for this purpose:

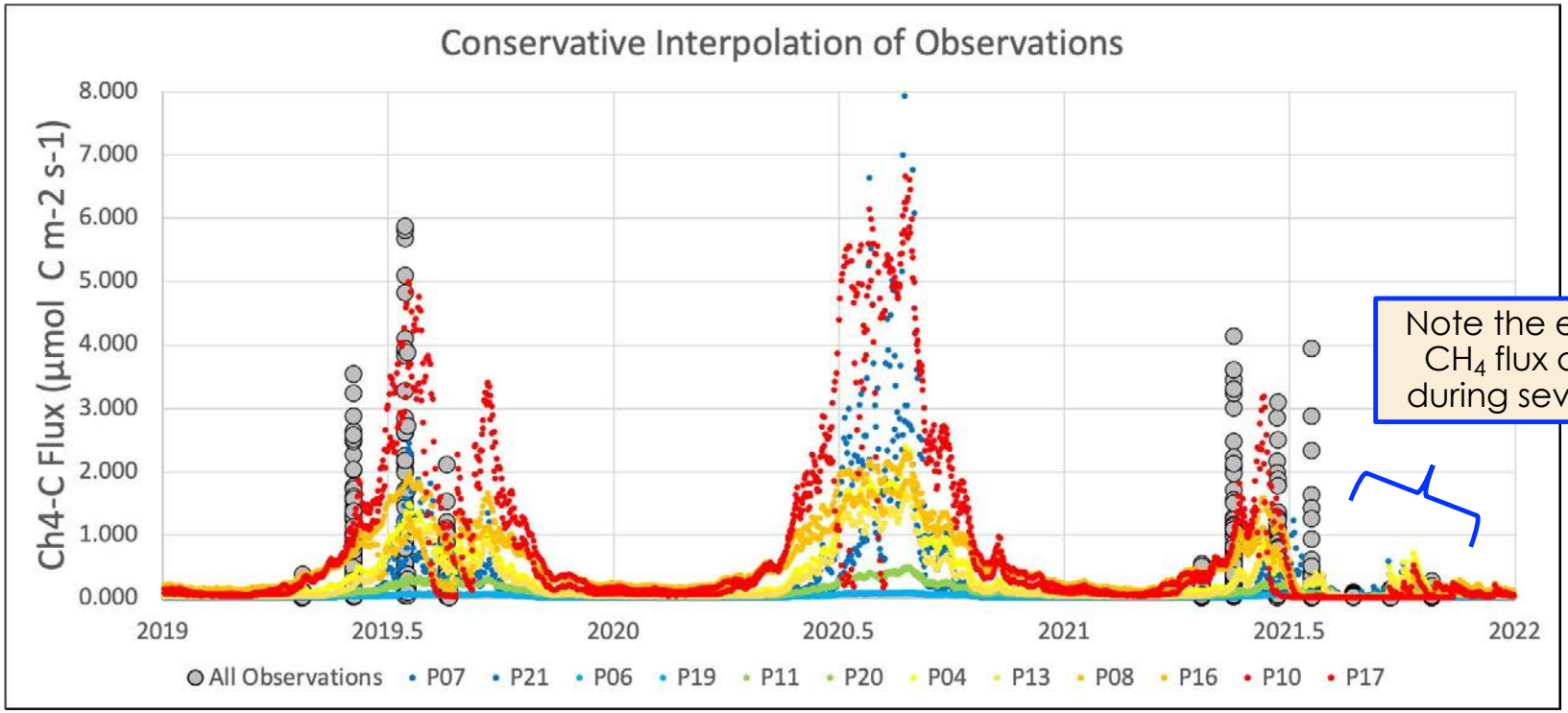
$$WT_{frac} = 1/(1+S^{(a*(x-(WT_{ref})))})$$

S = 2.7 (change function)
a = -0.2 (effective slope)
Wt_{ref} = -20 ("critical WT depth")

Specific parameter values by treatment were obtained by nonlinear regression or data assimilation processes.



CH4 Flux Interpolation By Treatment Showing 2019, 2020 and the 2021 Drought Year



Note the elimination of CH_4 flux as observed during severe drought.

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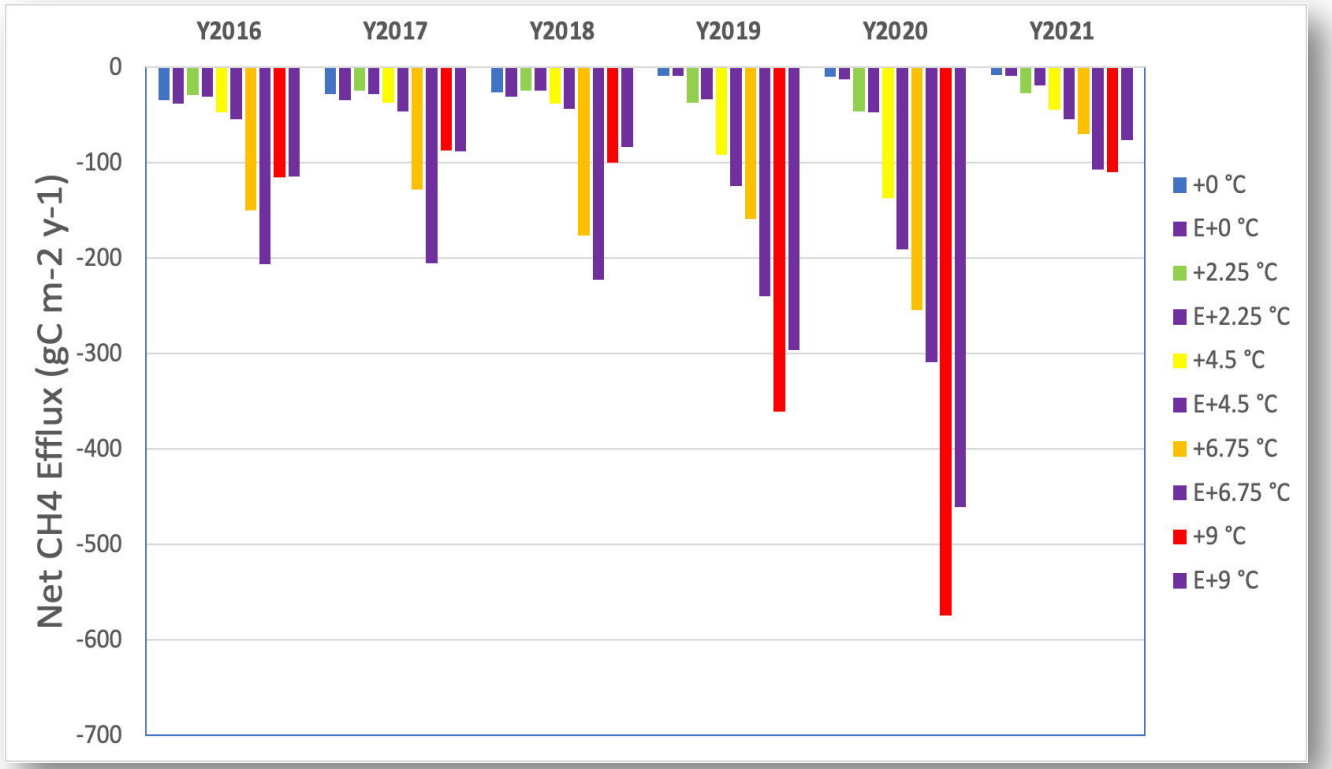
Interpolated C Losses from Net CH4 Efflux

- Net CH4 efflux had been increasing with cumulative years of warming, but 2021 drought conditions lowered water tables and dramatically reduced CH_4 losses.



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Can we use mechanistic models to reproduce these field observations? Not yet.

- We have been developing a version of the ELM land surface model to capture wetland functions (**ELM-SPRUCE**).
- Much progress has been made and we have demonstrated the utility of the methane cycle components of ELM-SPRUCE (Xu et al. 2016; Ricciuto et al. 2021; Yuan et al. 2021; Ma et al. 2022).
- However, the model needs to be improved to reproduce observed net CH_4 efflux reductions under drought. The current model was unable to reproduce the observed 2021 changes in water table heights.
- As a result, it could not simulate changing oxygen levels within the peat surface profile responsible for transitions away from methanogenisis.
- We are working to better represent the drought induced hydrologic conditions of 2021 to produce a wetland land surface model capable of making useful predictions for a range of future climate conditions. Thank you.