Modeling Climate Sensitivity of Biogeochemistry at Two Ponds in the Yukon-Kuskokwim Delta, AK

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Background

- Ponds and small lakes can have outsized CH_4 emissions compared with larger lakes and are numerous in high latitudes
- Processes controlling the magnitude and variability of CH_4 are poorly understood

In the Arctic, water bodies < 0.1 km^2 contribute to…

- 12% open water area
- 30% open water CH_4 emissions

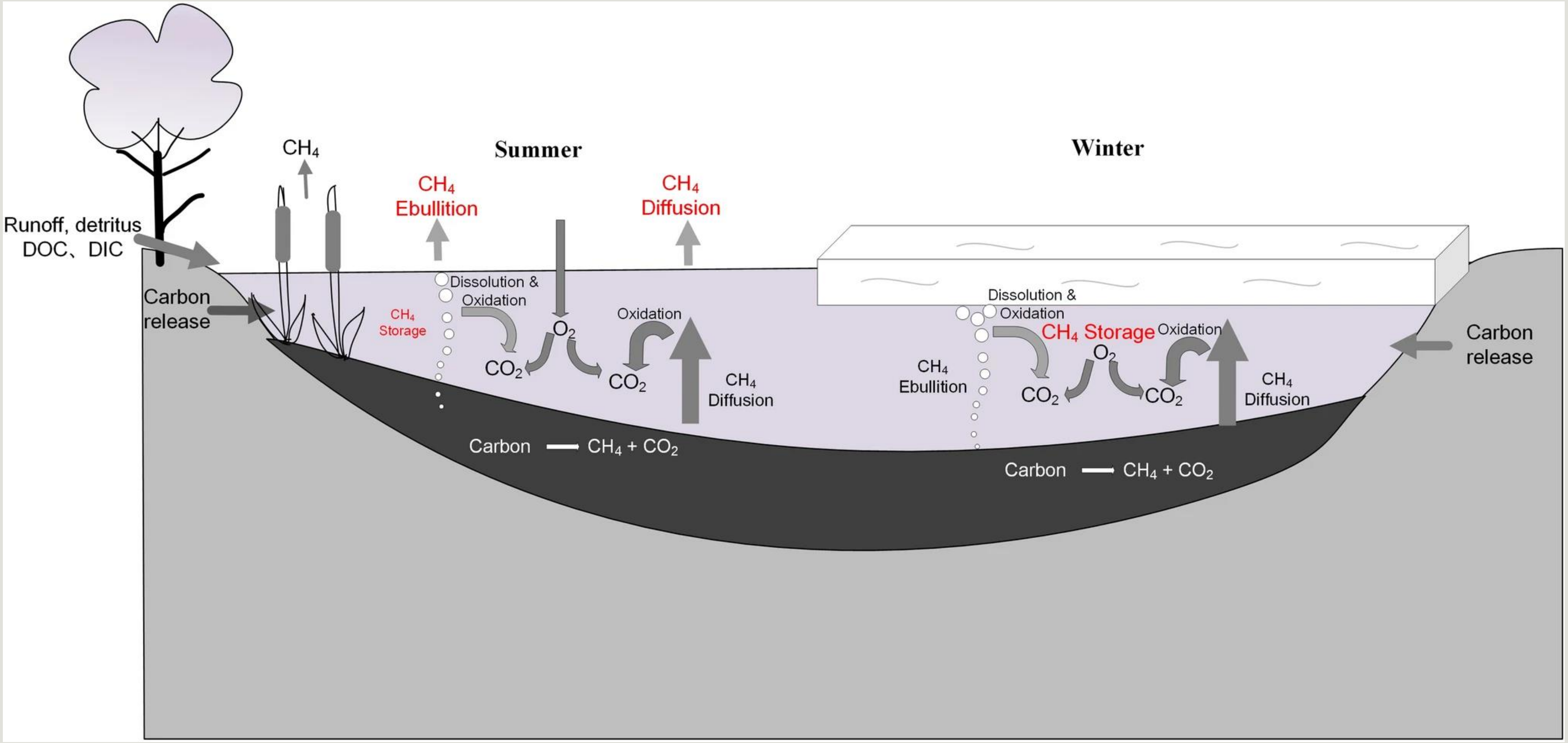
Kyzivat and Smith, 2023

Objectives

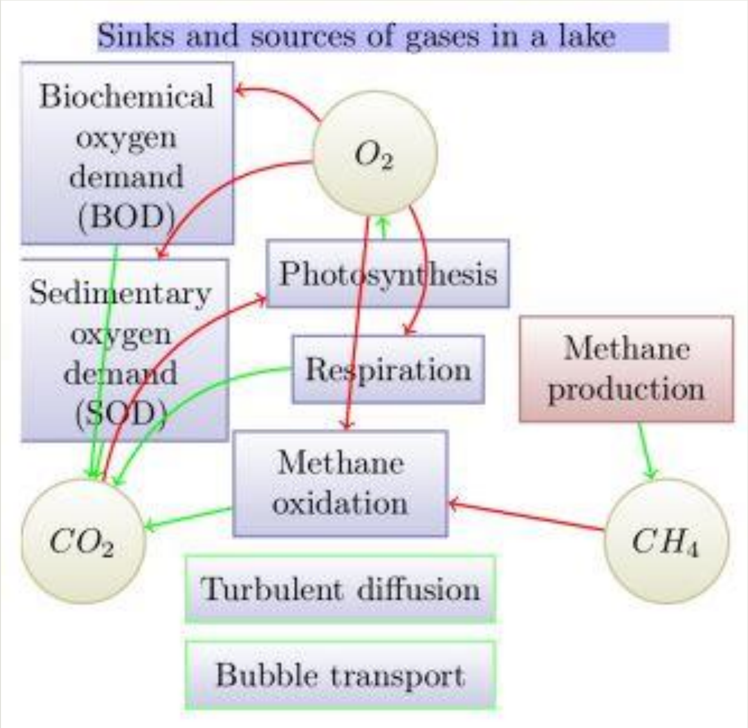
- Leverage in-situ measurements to constrain the LAKE model to simulate biogeochemical fluxes
- Develop understanding of LAKE model sensitivity to biogeochemical parameters and meteorological input

LAKE Model

Stepanenko et al., 2016



Lingling and Xue, 2021



Stepanenko et al., 2016

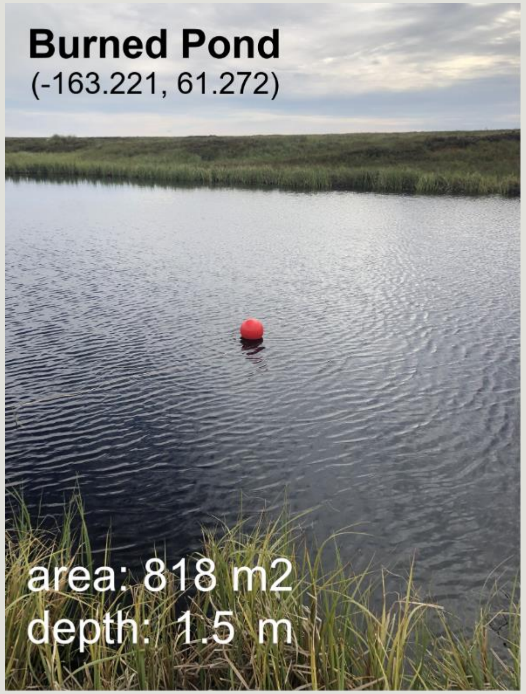
Study Area

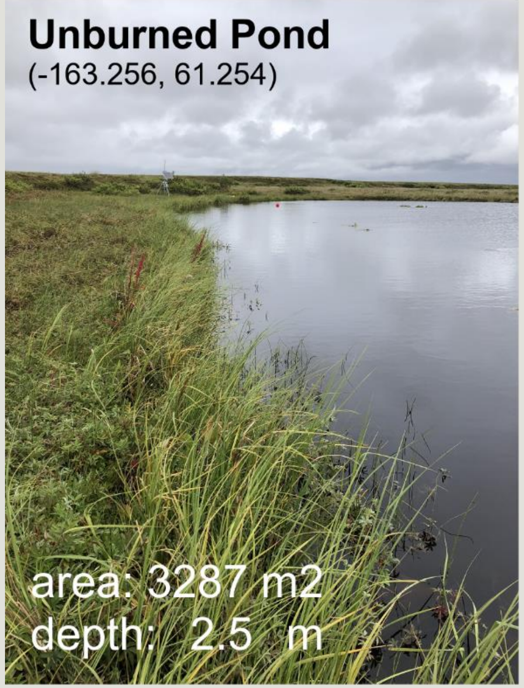
Eddy Covariance Towers

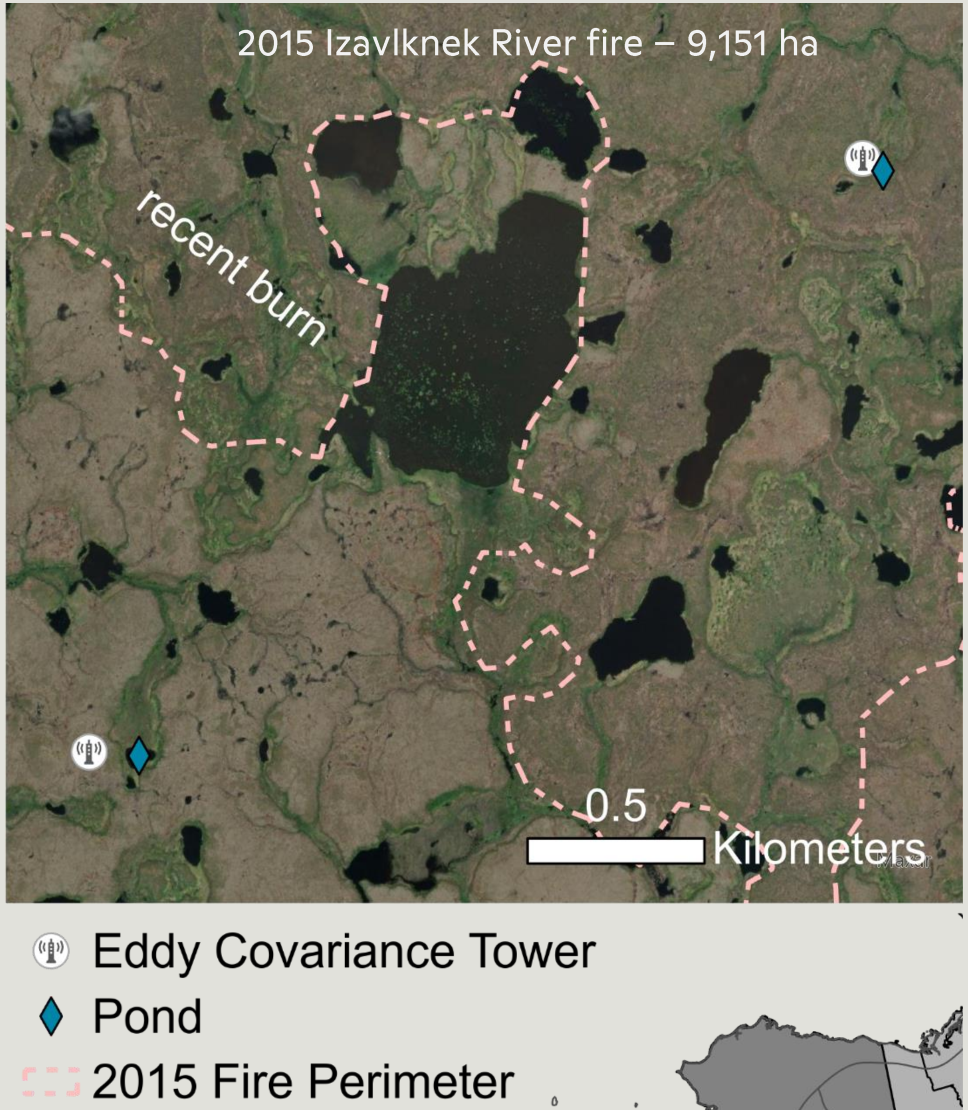
- Full meteorological suite
- Carbon fluxes

Aquatic

- Water temperature – continuous
- Dissolved CO_2 – continuous
- Dissolved CH_4 – water samples
- Dissolved O_2 – water samples
- Particulate Carbon – water samples







Meteorology

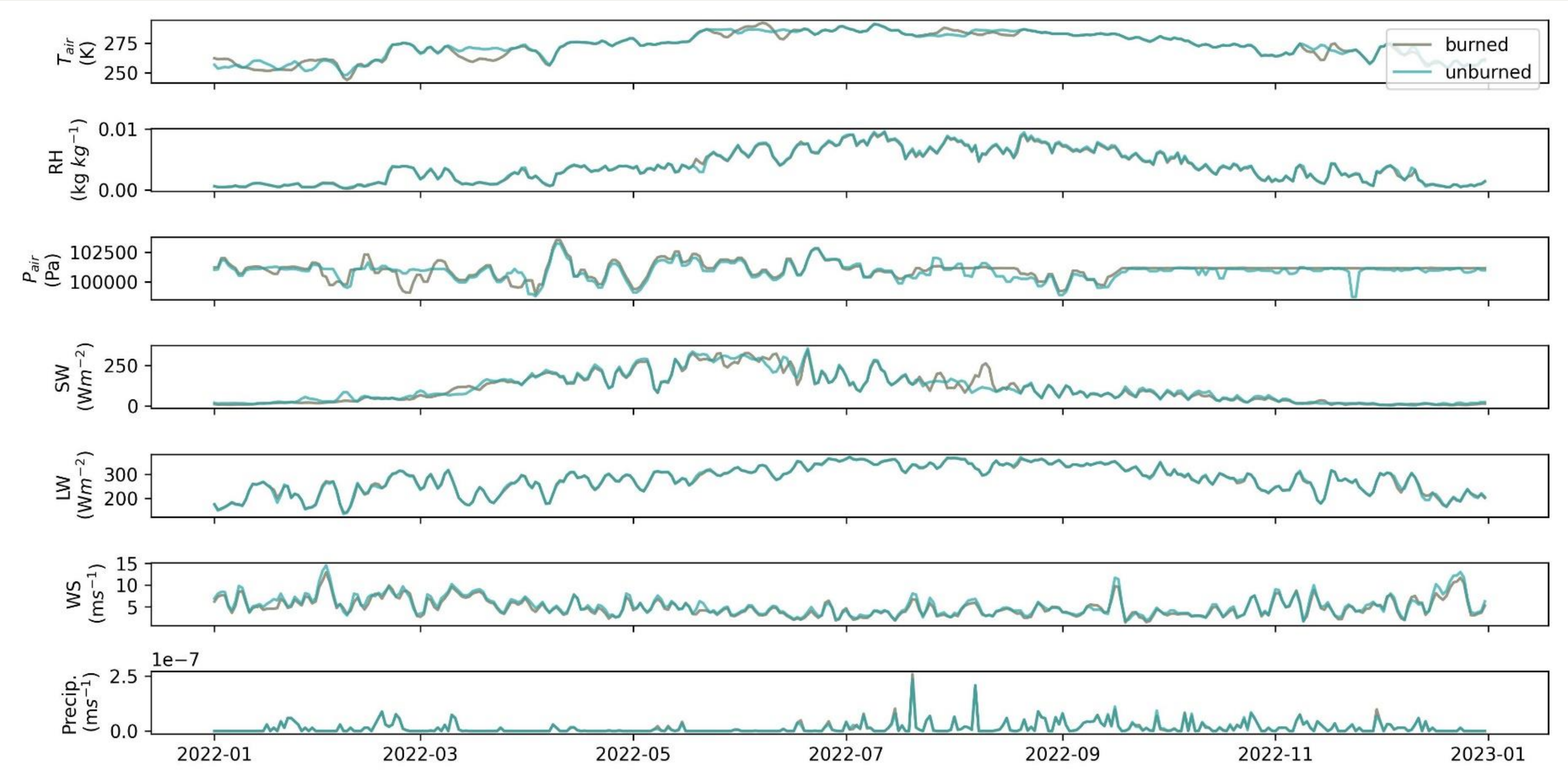
Winter air temp: -8 C
Summer air temp: 10 C
Rainfall: 450 mm

Input Data

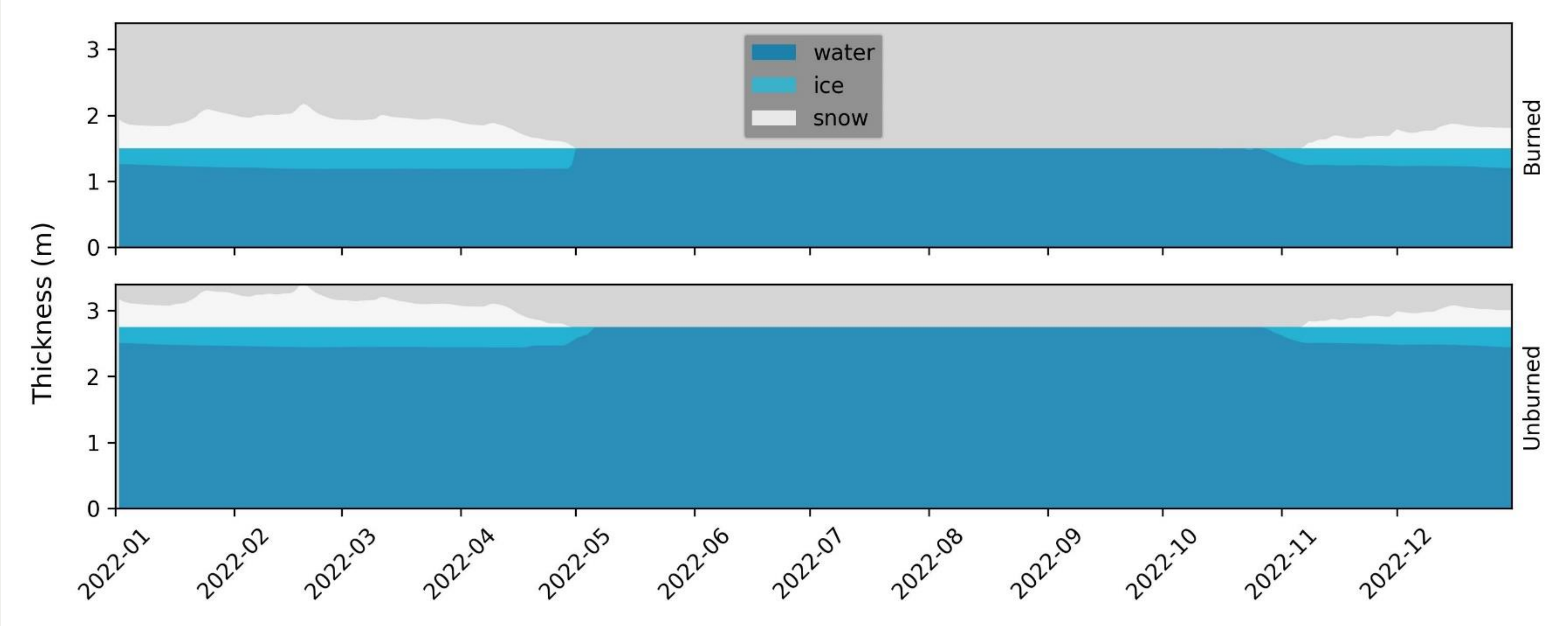
Inputs were compiled from two eddy covariance towers located within 100 m of each pond. Gaps were filled using bias-corrected data from the other pond's tower.

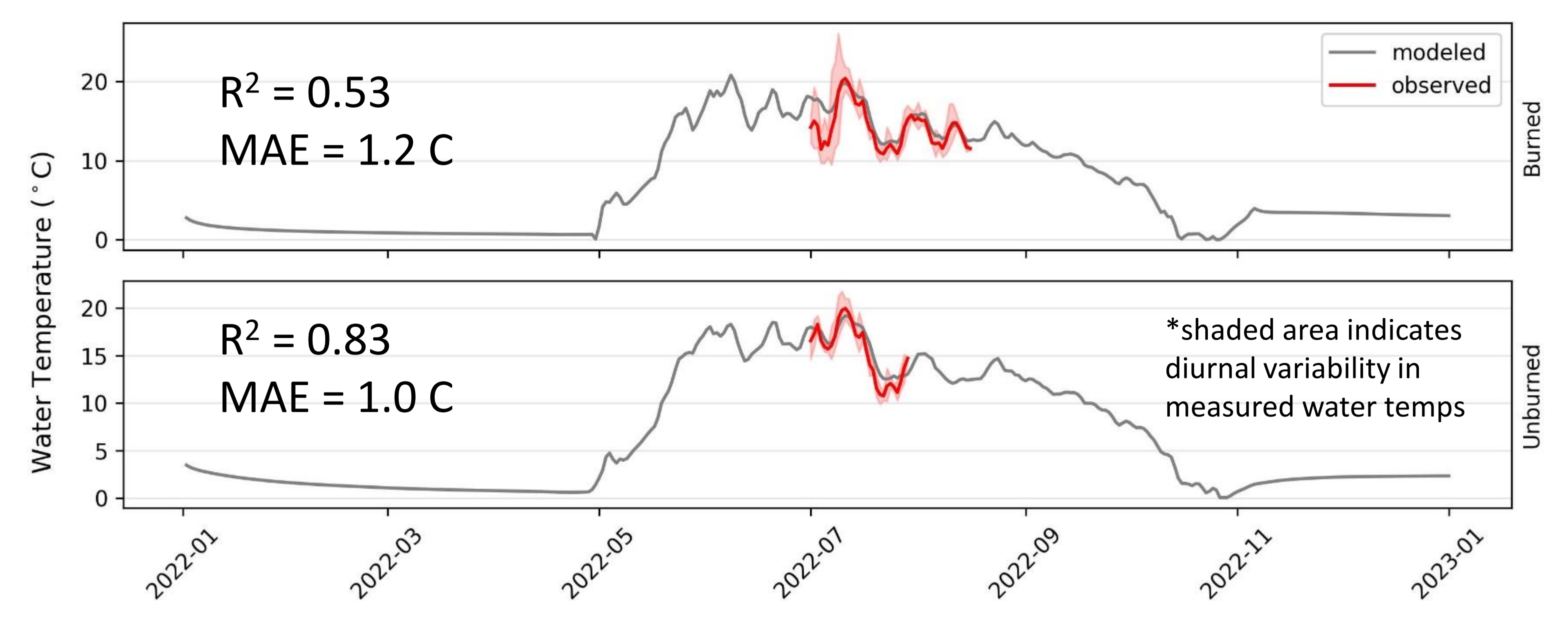
Spinup

2022 input data was smoothed and repeated over 50 years to spin up temperature and biogeochemical profiles.



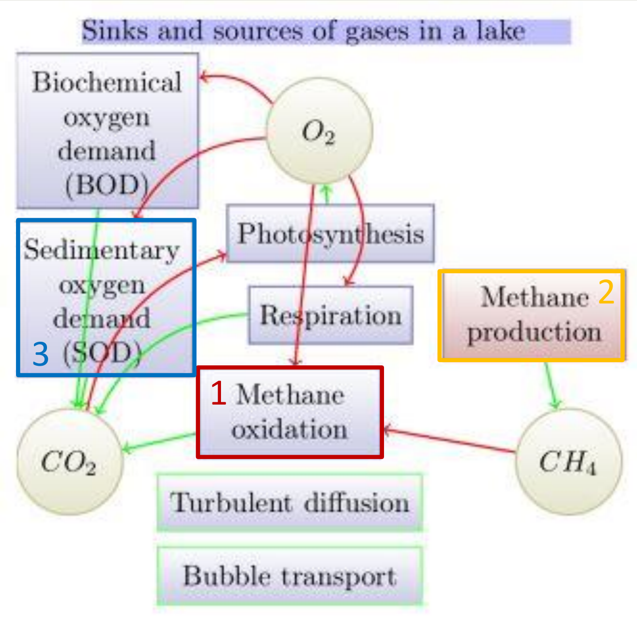
Layers & Temperature





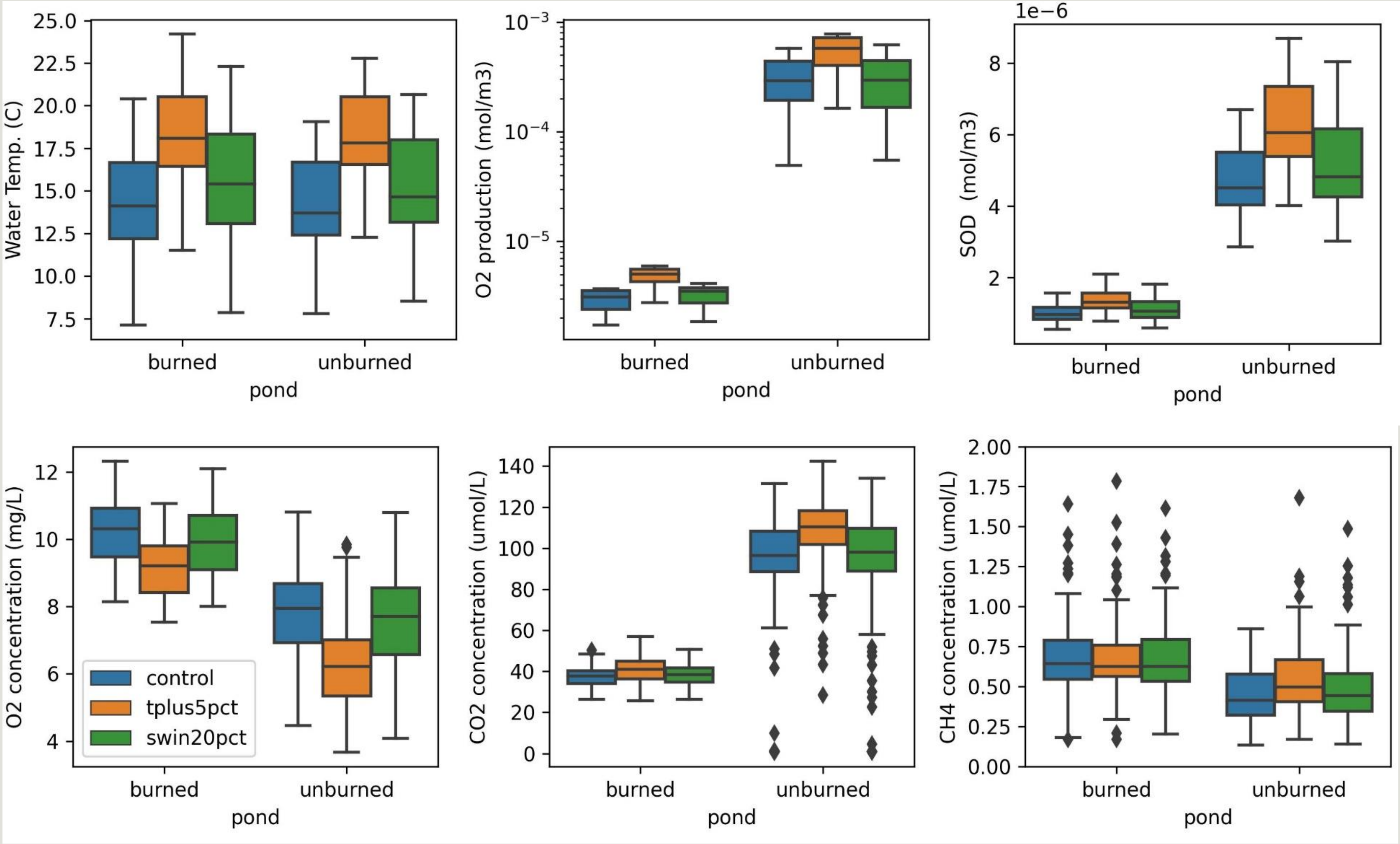
Parameter Sensitivity Analysis

parameter		burned		unburned	
		value	range tested	value	range tested
VmaxCH4aeroboxid		1.61E-10	1.0E-10, 8.0E-5	5.73E-08	1.0E-10, 8.0E-5
khsCH4		0.010556	1.0E-4, 5.0E-1	0.039912	1.0E-4, 5.0E-1
khsO2	1	0.002569	5.0E-7, 5.0E-1	0.000005	5.0E-7, 5.0E-1
r0methprod	2	0.000001	5.0E-11, 9.0E-6	3.98E-07	5.0E-11, 9.0E-6
kc0	3	4.66E-07	5.0E-9, 5.0E-5	4.21E-07	1.0E-8, 5.0E-4
mubeta0		0.000004	5.0E-7, 6.0E-5	0.000077	5.0E-7, 6.0E-4

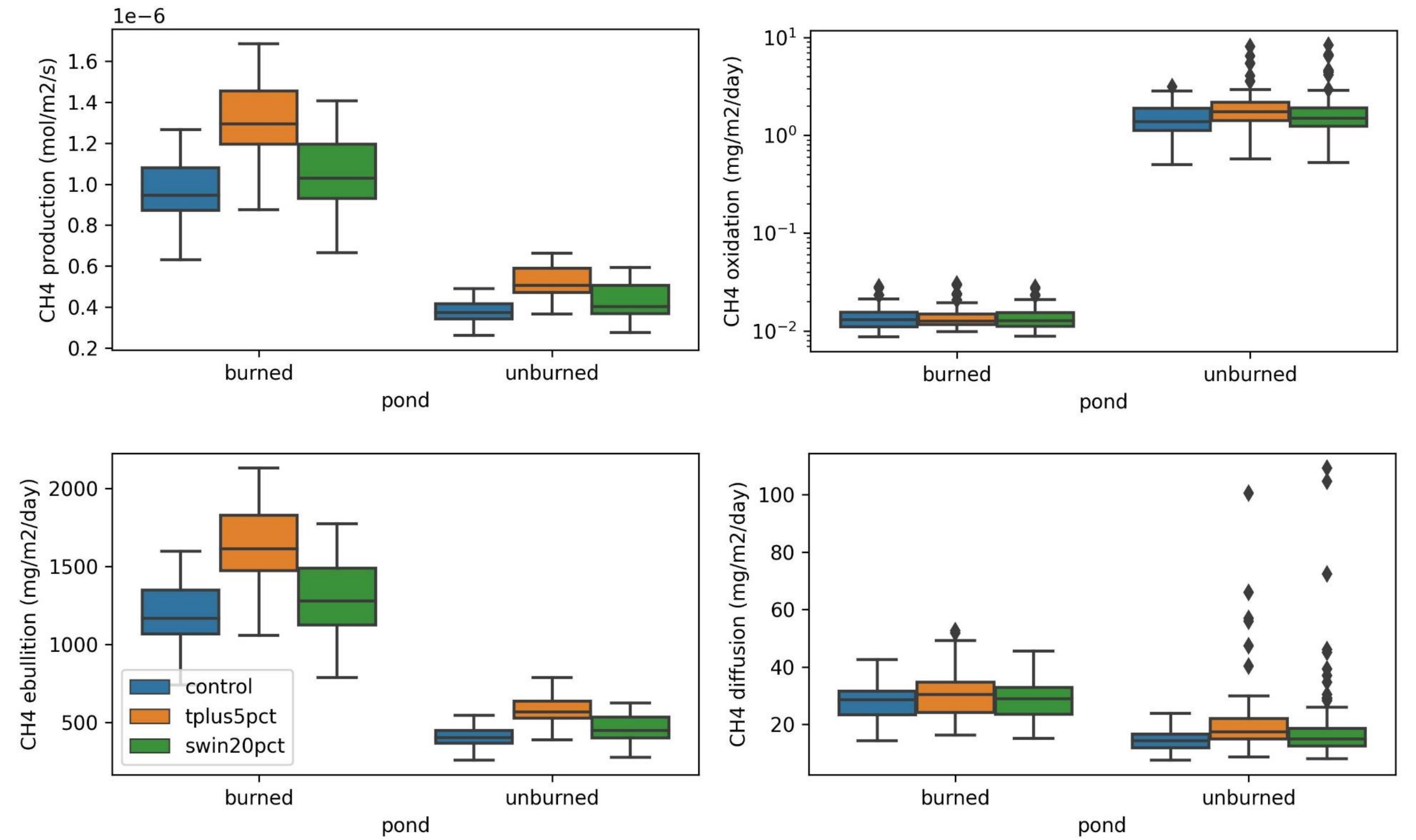


- Randomly sampled ranges of parameter values for six parameters controlling CH_4 production/oxidation and sedimentary oxygen demand (SOD)
- Matched model outputs with dissolved CO_2, CH_4, O_2 measurements
- Parameters with largest influence were r0methprod and mubeta0
- Sensitivity analysis was streamlined through parallel processing

Climate Sensitivity



- Imbalance between increasing CO2 production and CO2 uptake with increased temperature
- Increasing shortwave had negligible effect on biogeochemical activity and concentrations.



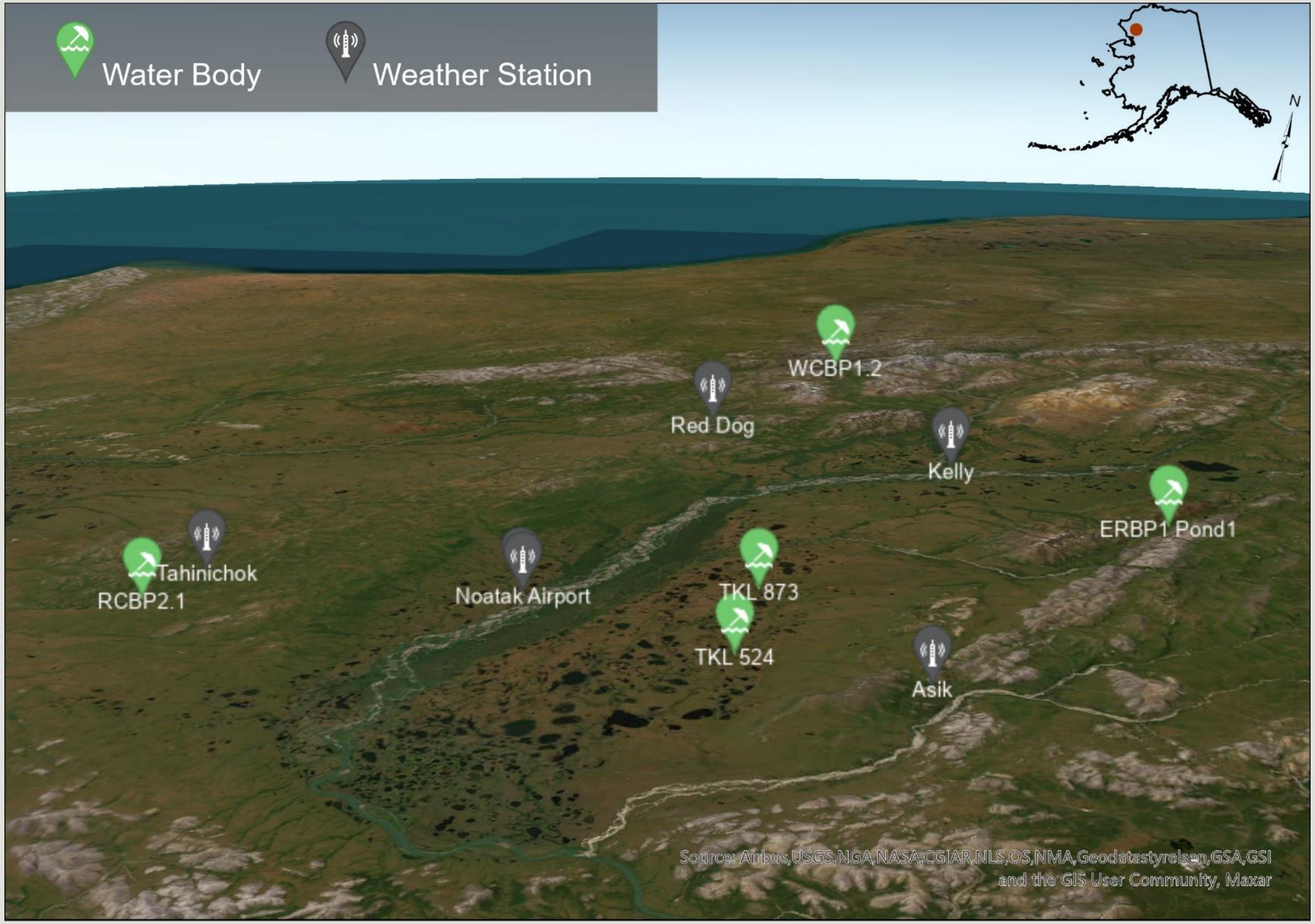
- Modeled CH_4 production highly sensitive to water temperature
- Over-production of CH_4 in sediments was required to match CH_4 concentrations
- Likely another source of CH_4 not accounted for

Conclusions

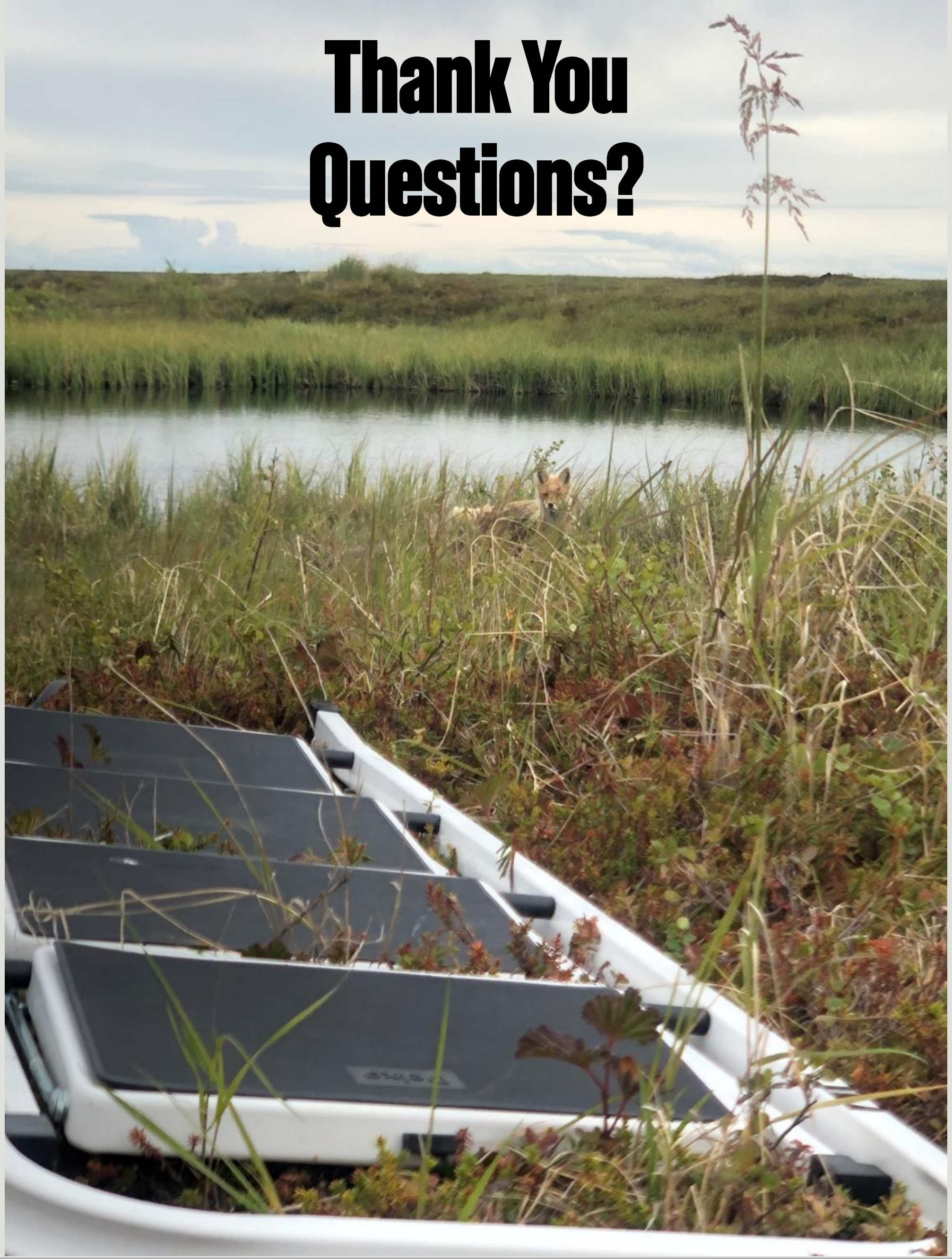
- LAKE model robustly models water temperatures
- Potentially high sensitivity of CO_2 and CH_4 to temperature
- Multiple ways to match limited observations
- Groundwater transport of CH_4 needs to be accounted for

Future Work

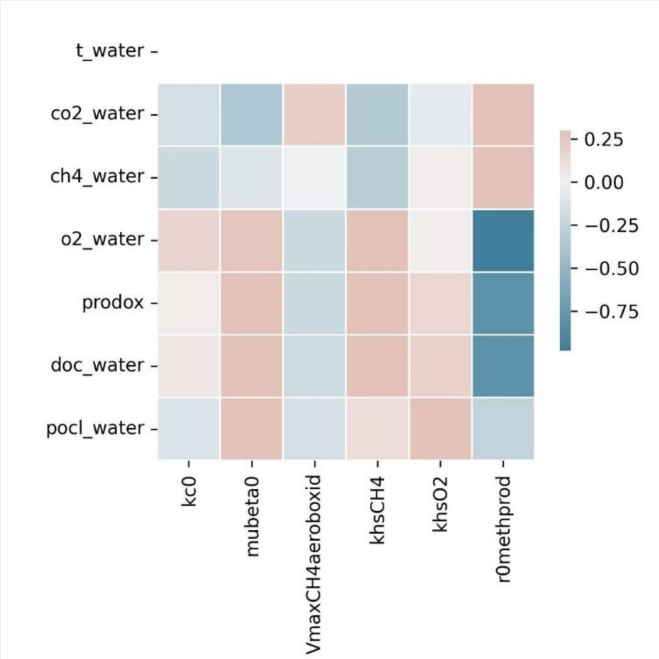
- Gather more data for YKD ponds to further constrain model at these sites and explore implications of fire on biogeochemistry
- Deploy model at three beaver ponds, two thermokarst ponds.
- Pair simulations with high resolution remote sensing of water bodies



Thank You
Questions?



Parameter Sensitivity Analysis



		Mean	SD	MAE	r2
Unburned	twater (C)	16.116	2.19123	1.686373	0.8
	co2 (umol/L)	104.9536	15.79947	16.30544	0.6
	ch4 (umol/L)	0.366479	0.095806	0.433079	
	do (mg/L)	6.865381	1.156757	6.740244	
	doc (mg/L)	0.22579	0.383504		
Burned	twater (C)	15.46458	2.220496	1.289083	0.51
	co2 (umol/L)	37.43219	5.112188	8.149654	0.22
	ch4 (umol/L)	0.627946	0.126835	0.227262	
	do (mg/L)	9.941103	0.688051	0.766687	
	doc (mg/L)	0.004999	0.001565