Carbon Dioxide Exchange Responses to Changes in Water Table and Surface Warming of Coastal Tundra at Barrow, Alaska

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Arctic systems

- Soils: >190 Gt
- Land plants: 2.3 Gt
- Extreme seasonality, and low soil temperatures
- Continuous permafrost, complex hydrology
- Highly affected by changes in temperature
- Snowmelt very important, low precipitation
- Low evaporation
- Highly specialized species

Expected changes

- Temperature increase
- Longer thaw seasons
- Increase drying
- Increase permafrost degradation, erosion, draining, and flooding
- Increase microbial activity
- Increase in organic matter turnover and nutrient availability

In the short term, changes in hydrology may have larger effects on ecosystem carbon balance than changes in temperature

Overall question?

What are the effects that changes in temperature and water availability have on the CO_2 and CH_4 fluxes?

Hypothesis

short-term

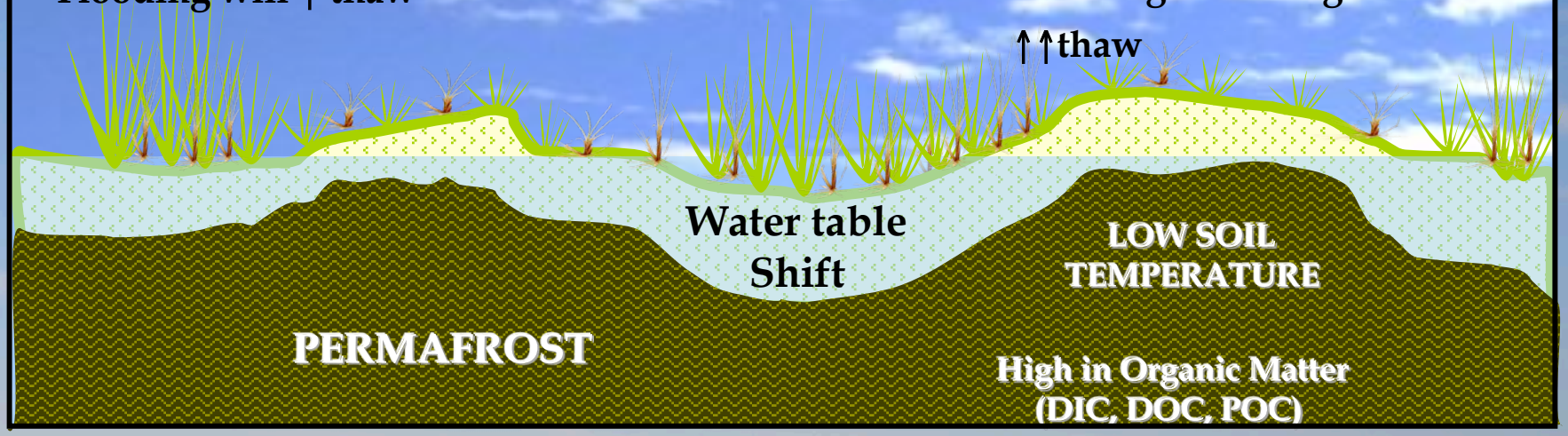
CO_2/CH_4

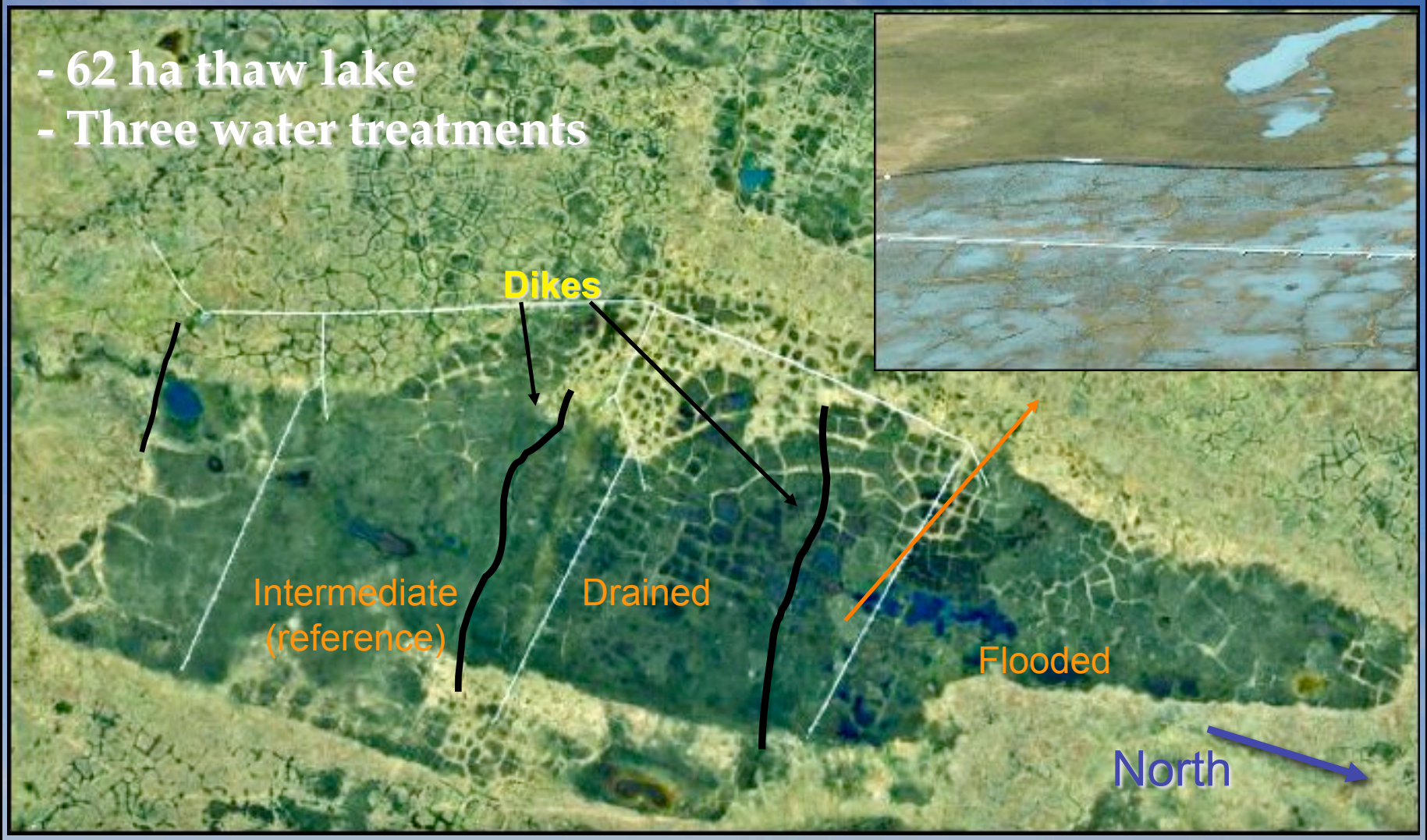
Water table shifts

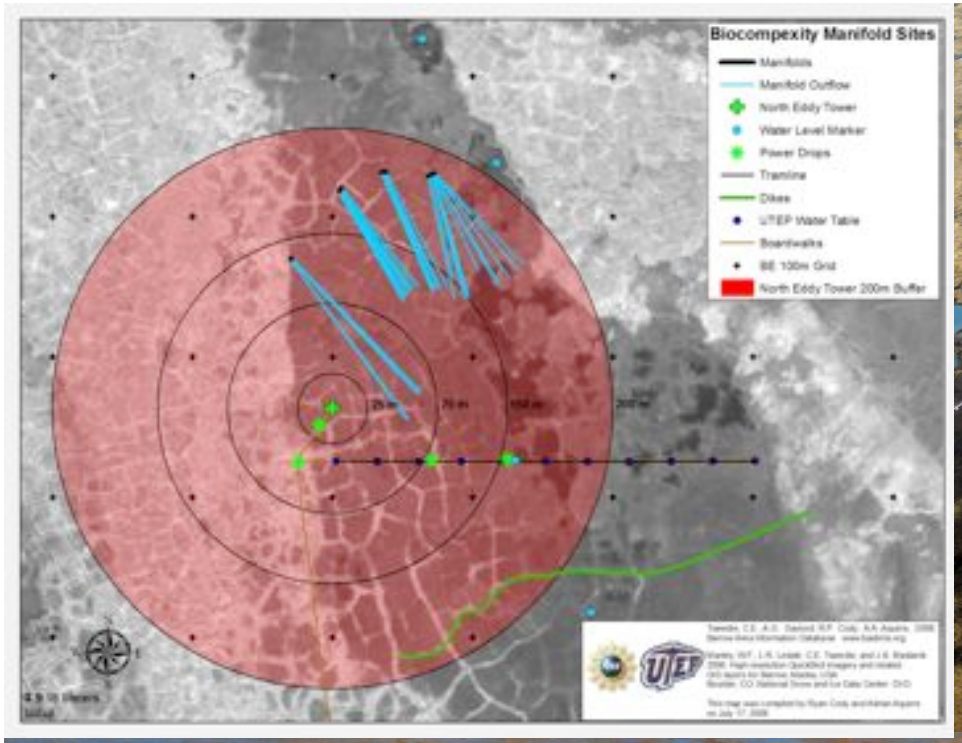
- Drying will ↑ soil O_2, ↑ CO_2 and ↓ CH_4
- Flooding will ↓ soil O_2, ↓CO_2 and ↑ CH_4
- Soil drying will ↑insulation and ↓ thaw
- Flooding will ↑ thaw

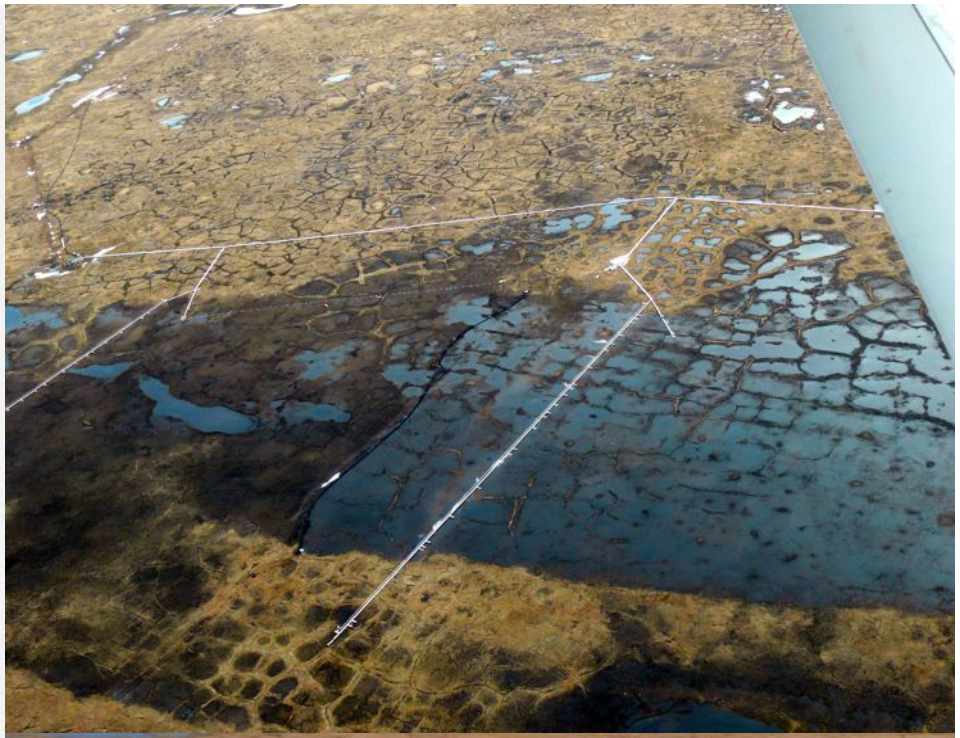
Water table shifts + warming

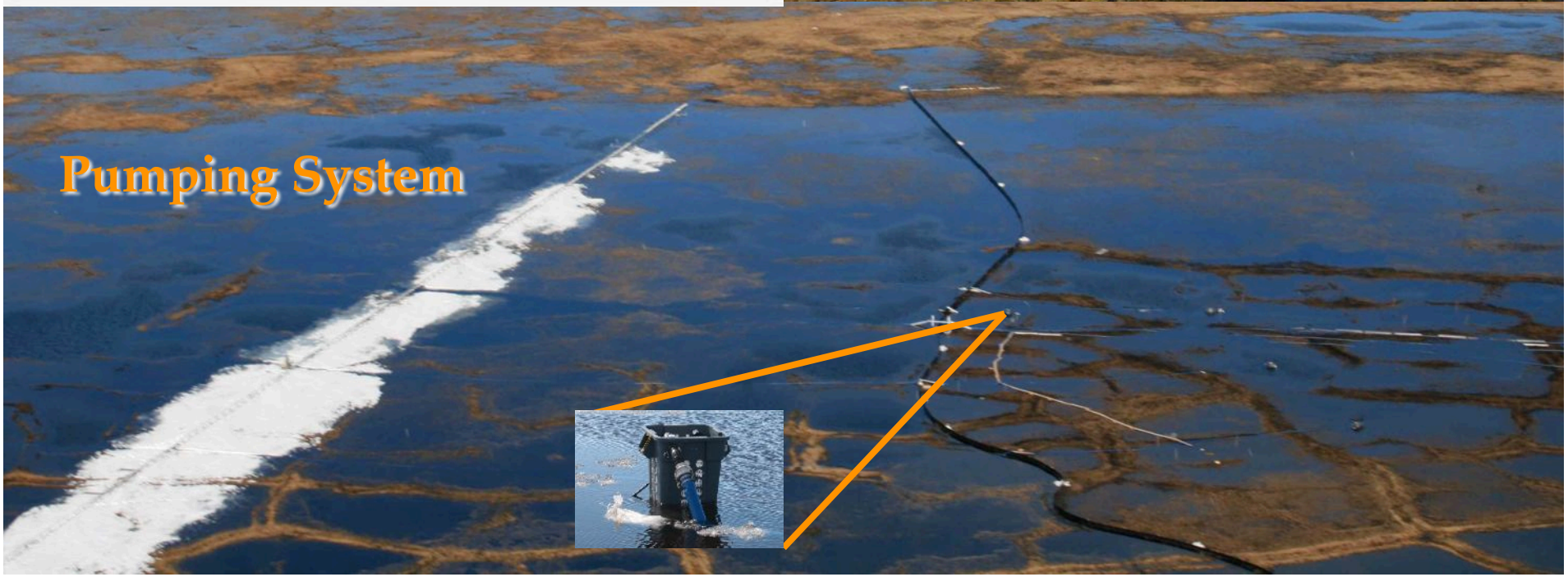
- Drying+warming = ↑ soil O_2,↑↑ CO_2 and ↓ CH_4
- Flooding+warming will ↓ soil O_2, ↓ CO_2 and ↑↑ CH_4
- Soil drying+warming ↑insulation and ↓ thaw
- Flooding+warming will ↑↑thaw




- 62 ha thaw lake
- Three water treatments
Dikes
Intermediate
(reference)
Drained
Flooded
North


Biocompexity Manifold Sites
Manifolds
Manifold Outflow
North Eddy Tower
Water Level Marker
Power Drops
Tramline
Dikes
UTEP Water Table
Boardwalks
BE 100m Grid
North Eddy Tower 200m Buffer




Pumping System

- 6 temperature control plots per treatment,
  Total 18 CTL plots
- 6 temperature treated plots (OTC)per treatment,
  Total 18 OTC plots

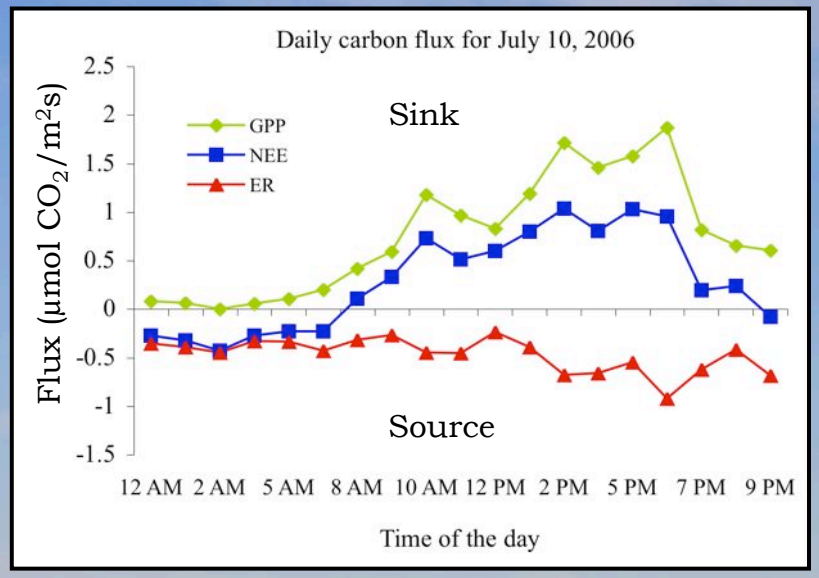
CO_2 assessments

- Static Chamber techniques: Infrared Gas Analyzer, LI-6200 (LI-COR Inc.).
- NEE=GPP-ER

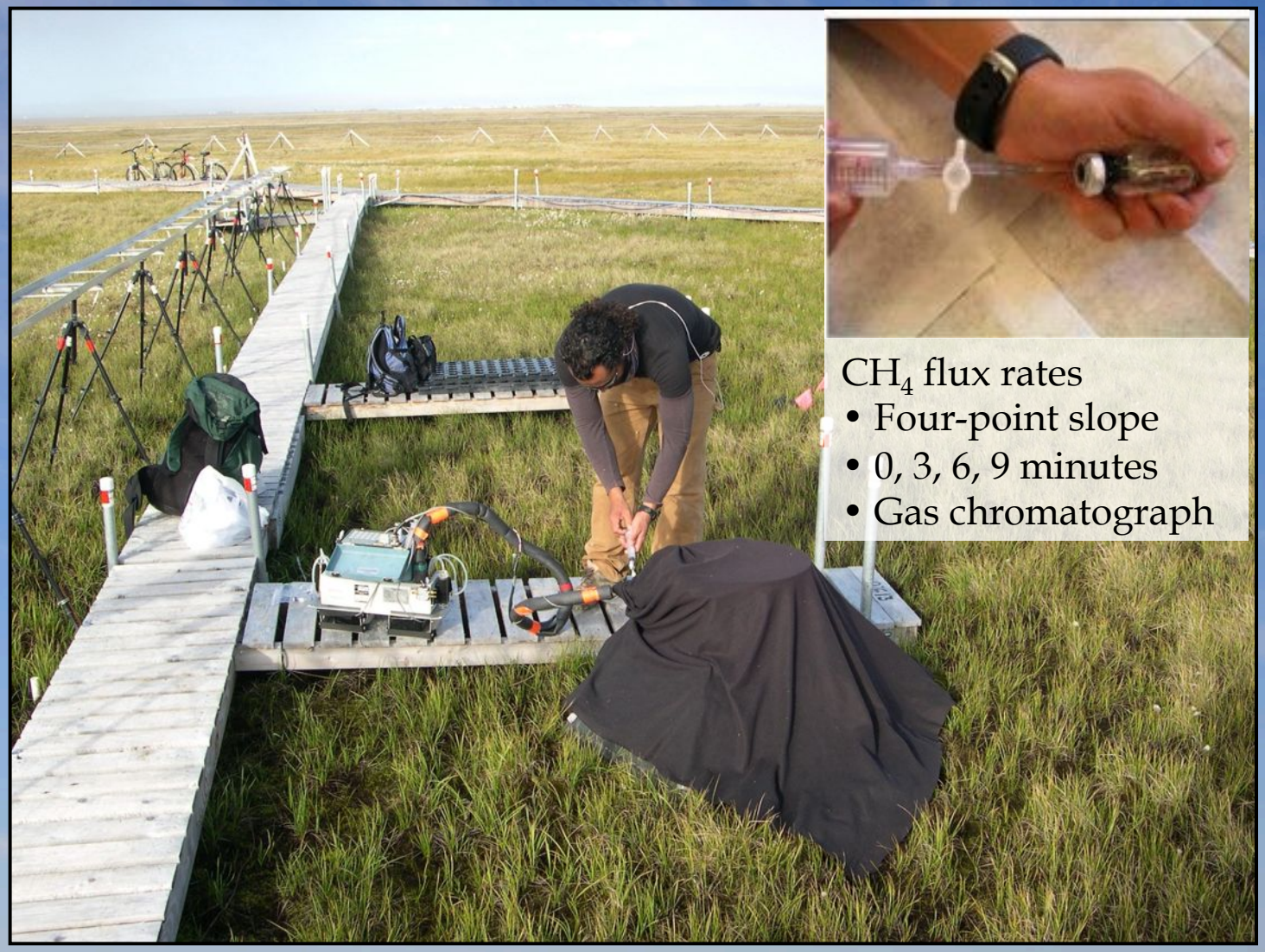
  Gross primary productivity (+ GPP)

  Net ecosystem exchange (NEE) (+ or -)

  Ecosystem respiration (- ER)



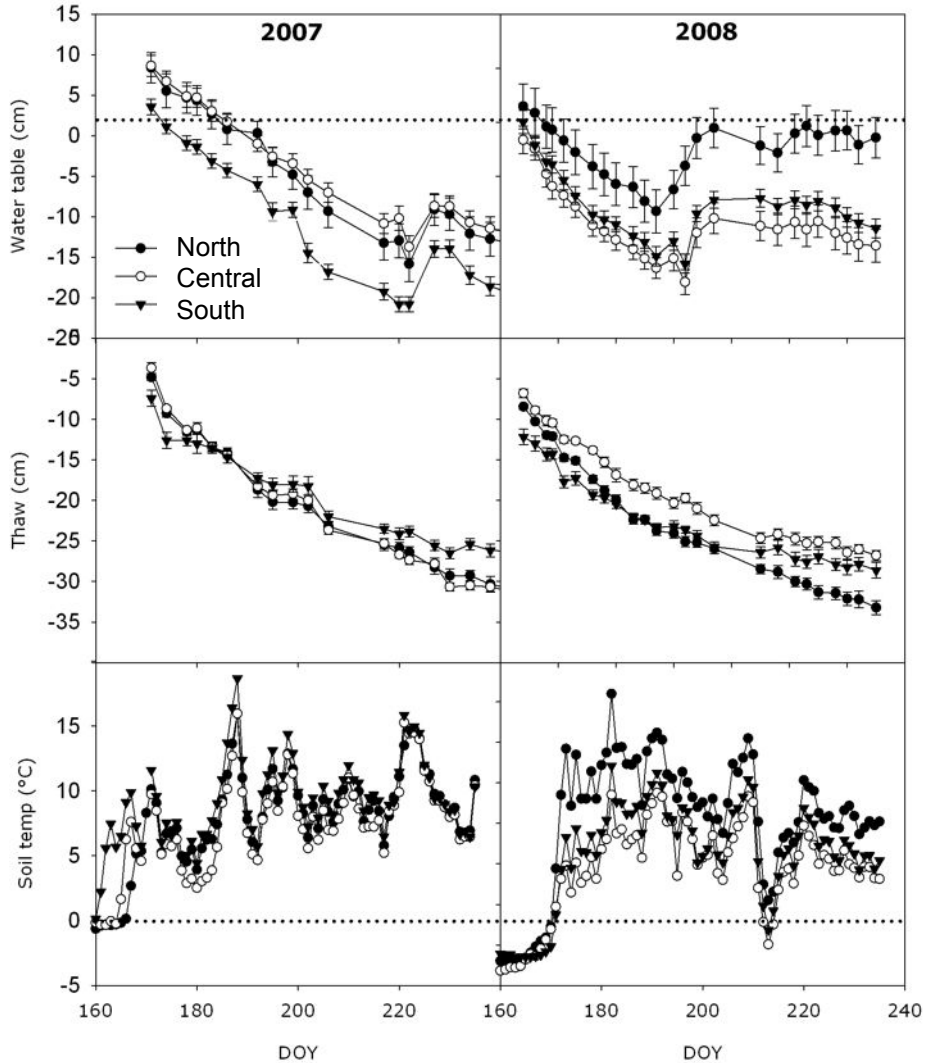
Methane



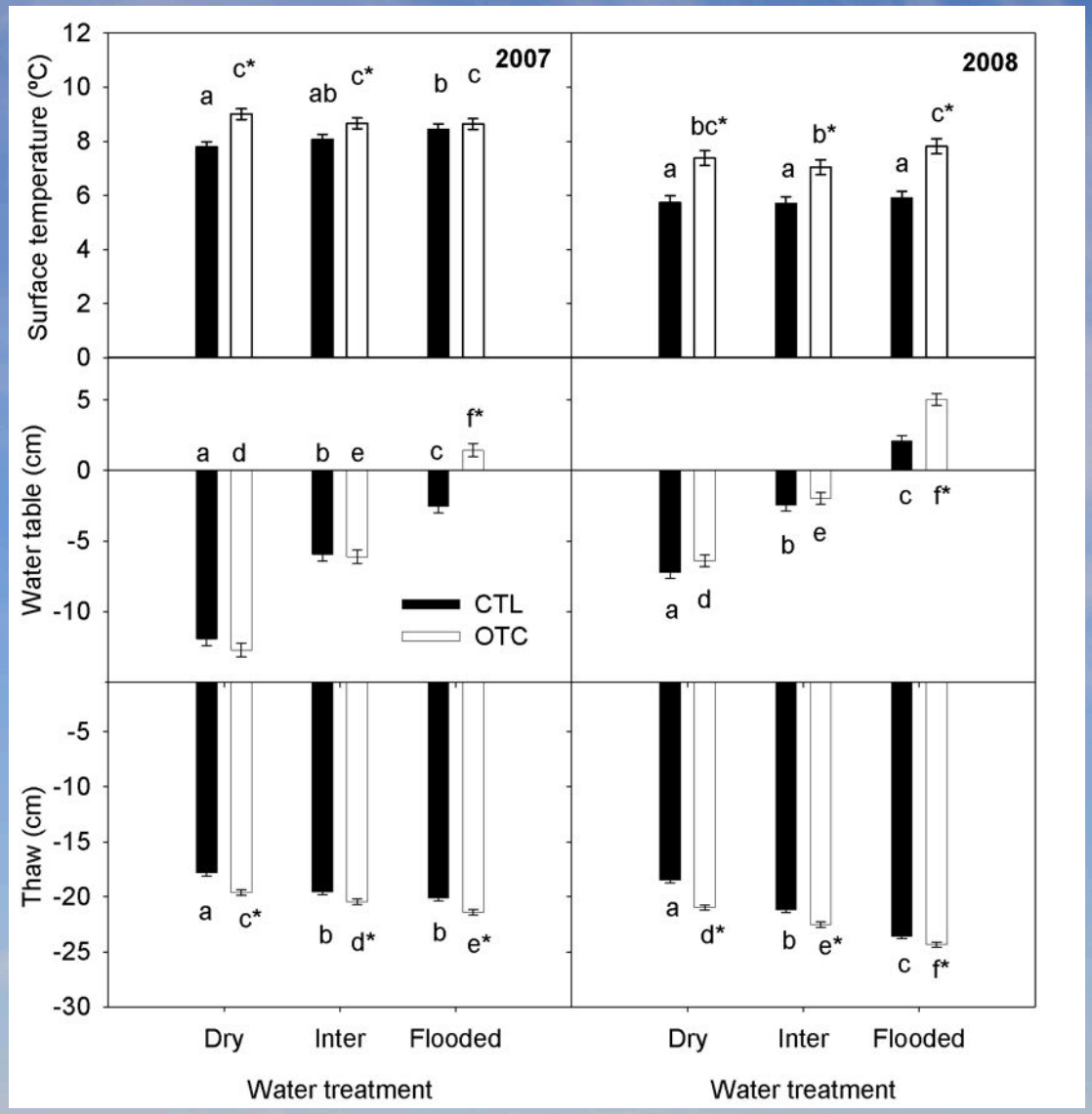
CH_4 flux rates

- Four-point slope
- 0, 3, 6, 9 minutes
- Gas chromatograph

Seasonal conditions

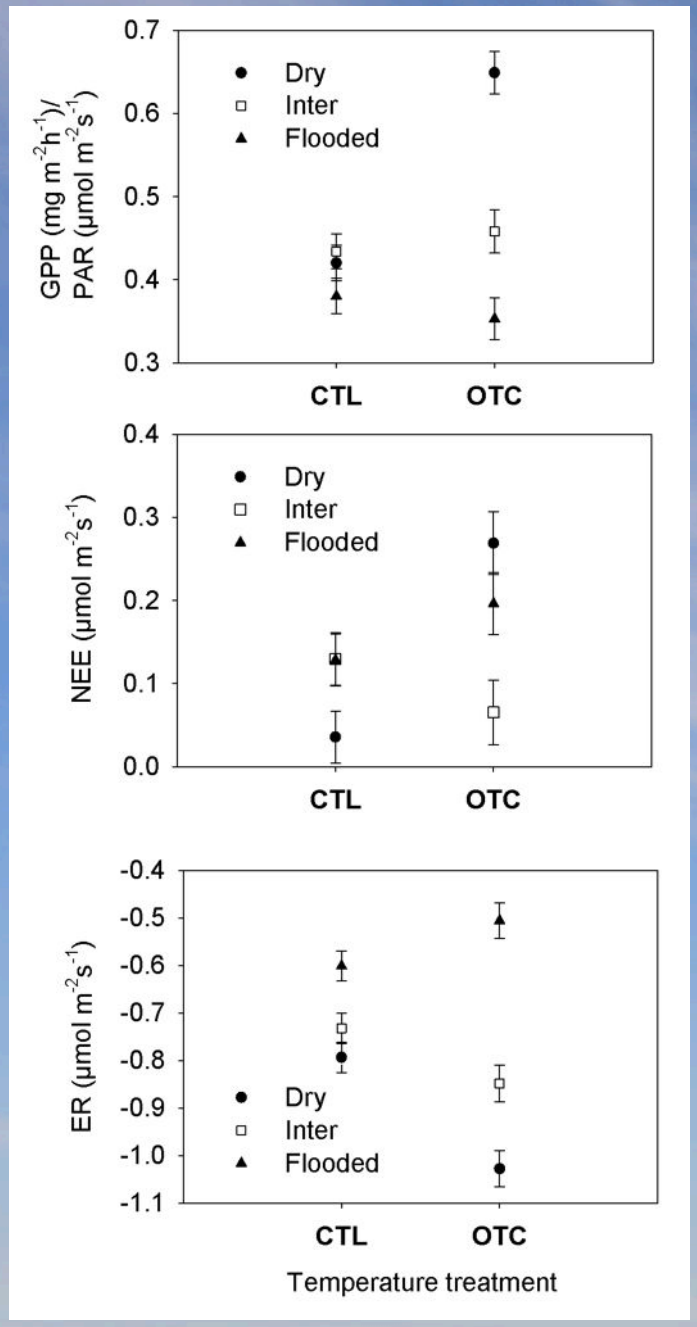


Water table and temp trts



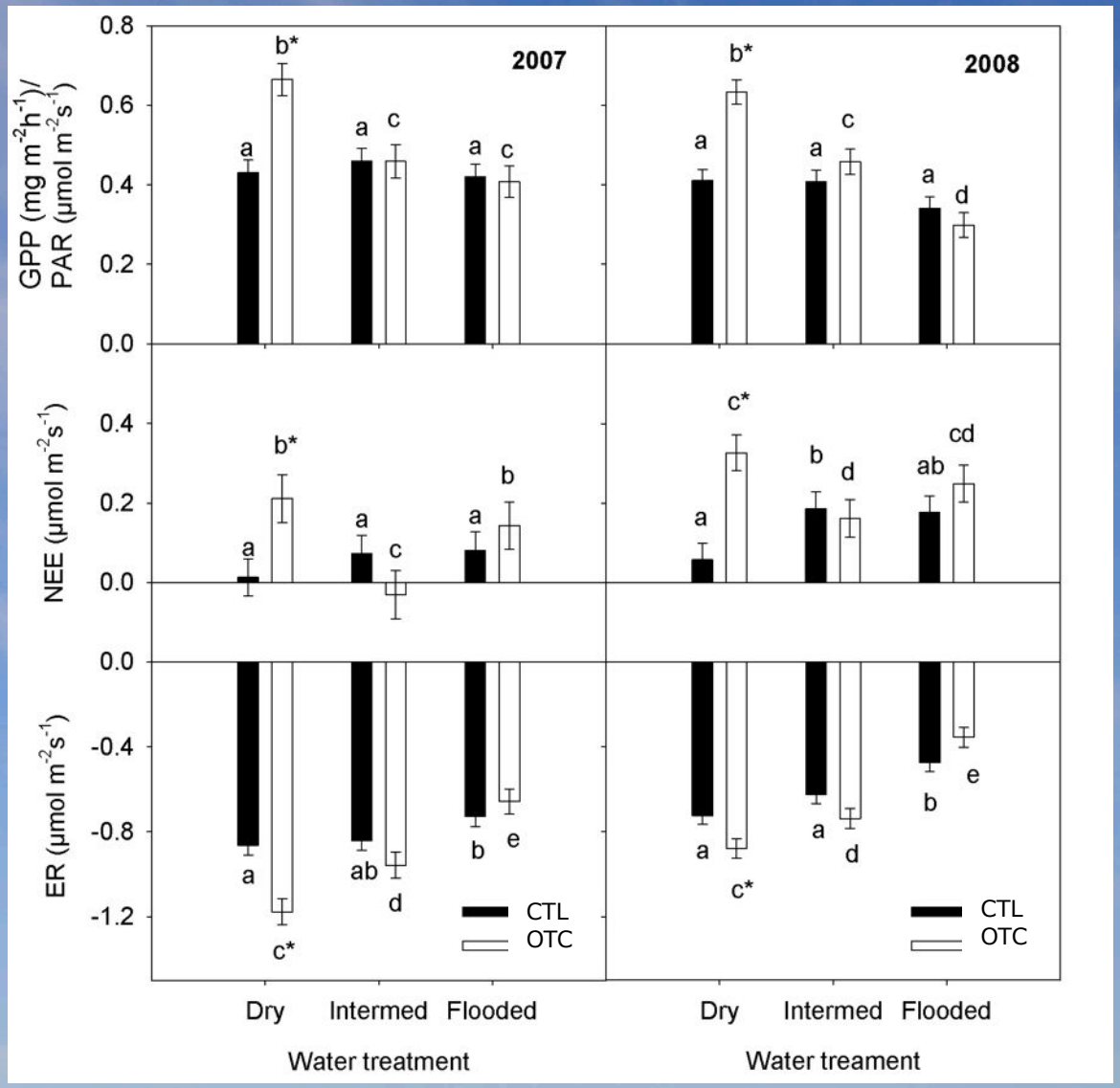
- Warming was significant (*p<0.05)
- Water table differ between treatments (p<0.05)

- Deeper thaw was positively related to increased water availability
- Warming positively affected thaw
- Dry conditions reduced thaw



Treatment Effects

- Year and Temp trt significantly affected all CO_2 flux components
- Water table trt had significant effects on GPP and ER ($p<0.001$), but not on NEE ($p=0.34$)
- 3-way interactions significant ($p<0.0001$)



- All CO_2 components were positively affected by warming
- Water table shifts affected both GPP and ER

GPP and ER models

$$GPP = GPP_{max(PPFD,WT)} * \frac{PPFD}{(k+PPFD)} * \exp\left(-0.5*\left(\frac{WT-uGPP}{tGPP}\right)^2\right) * NDVI$$

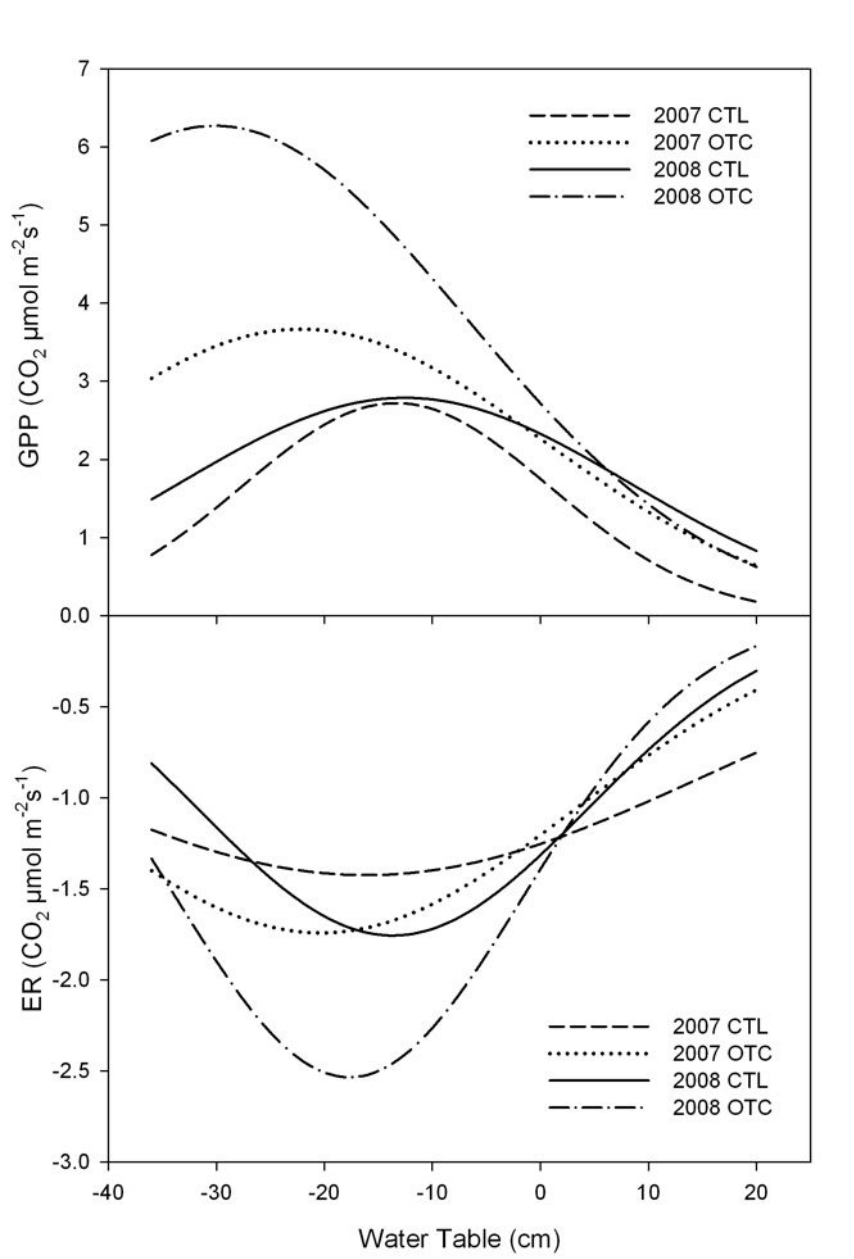
Where:

$GPP_{max(PPFD,WT)}$: maximum GPP
PPFD: photon flux density,
WT: water table
k: is the PPFD at which GPP rate is half of the GPP_{max},
NDVI: normalized difference vegetation index
uGPP: optimum water table position for GPP_{max}
tGPP: tolerance or water table range for optimal GPP

$$ER = ER_{max(WT)} * \exp\left(-0.5*\left(\frac{WT-uER}{tER}\right)^2\right) * NDVI * \exp(c*T)$$

Where:

$ER_{max(WT)}$ Maximum ER
WT : water table,
uER: optimum WT position
tER: tolerance or water table range
NDVI: is the normalized difference vegetation index
c:rate and direction of the ER in a temperature range
T:air temperature



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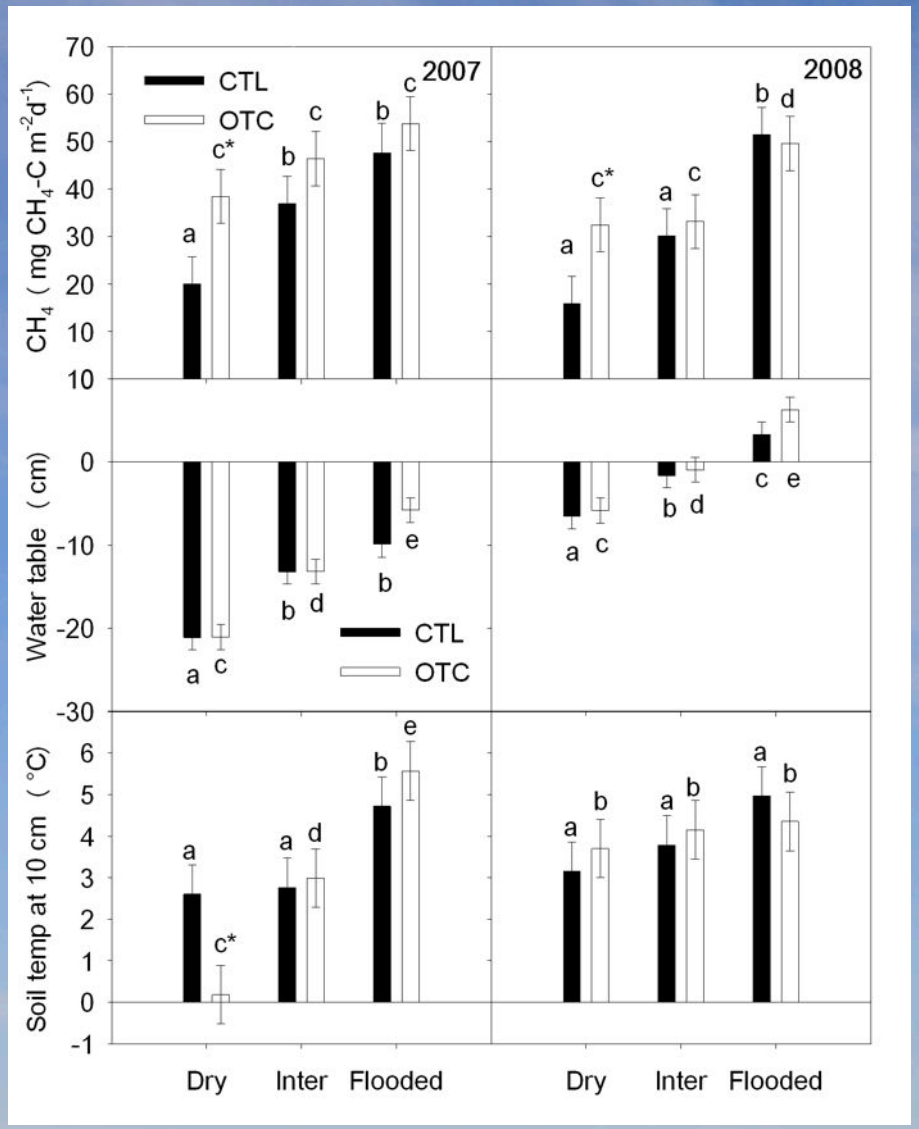

- No difference between years (p=0.129)
- Water trt (p<0.0001)

  Dry<Inter<Flooded
- Temp trt (p=0.012)

  CTL<OTC

- Warming increased CH_4 flux in all water conditions
- Positive correlation WT and CH_4 flux

Conclusions

- Warming had a magnifying effect on GPP and ER, differences between water treatments larger in OTCs
- Warmed dry sites presented highest GPP, NEE and ER
- ER responds more strongly to water table changes between surface and -10 cm
- Although soil temperature importantly controls ER, near the surface water table could be a stronger controller of ER
- Contrasting weather conditions between years did not affect CH_4 flux
- Strong interaction between water table, soil temperature and thaw

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