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Greenhouse gas flux responses to eCO2 and increased temperatures

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U.S. DEPARTMENT OF ENERGY

Objectives

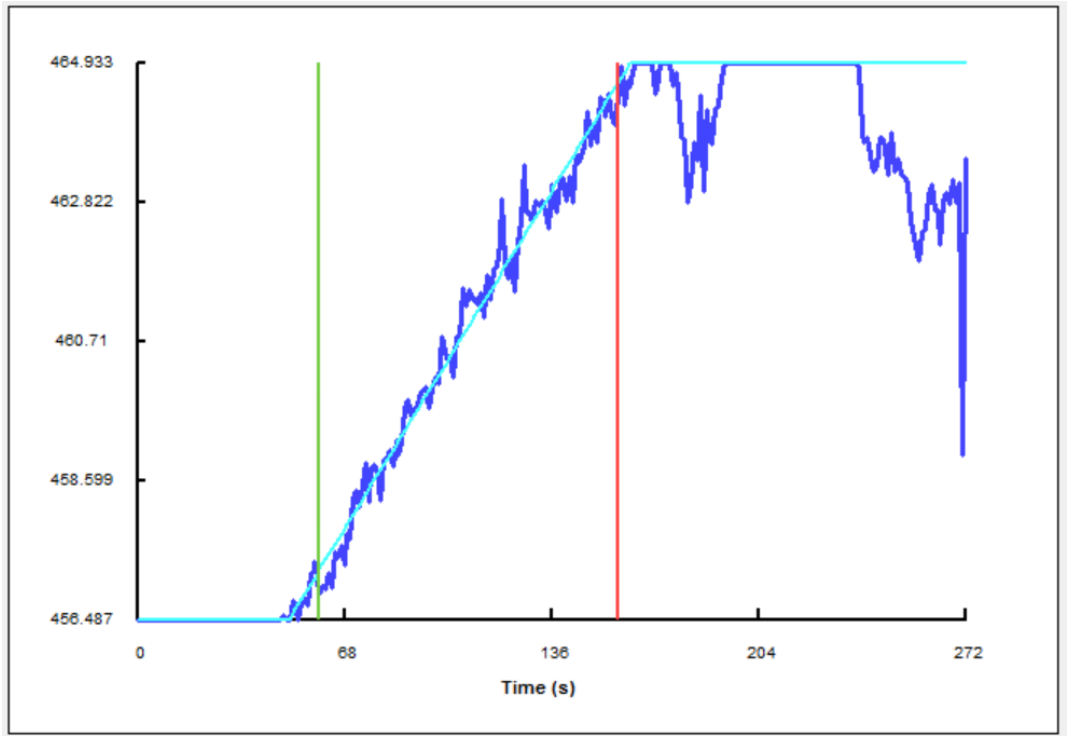
- **Characterize the CO_2 and CH_4 emission from the moss-shrub ecosystem**
  - **Moss-shrub ecosystem: Everything in the experimental peatland except large trees (moss, shrubs, forbs, sedge, grass, fungi, microbes…)**
- **Replacement for P. Hanson large-flux collars**
  - **1-2 measurements per year**
- **Higher temporal resolution Autochamber (Eosense)**
  - **4 measurements per hour**
- **Response across treatments**
  - **ecosystem warming (+0, +2.25, +4.5, +6.75, +9°C)**
  - **and elevated CO_2 (eCO_2: +500 ppm)**
- **Q_{10} equations for models**
- **Response to other environmental variables (SPRUCE)**

Large flux collars (1.2 m)

Small flux collars (50 cm)

Method

- **Measure Growing season fluxes (April – October) 2022-2024**
  - **Eosense clear-top chambers with ABB GLA-131 GGA gas analyzer**
  - **Two domes per temperature treatment (measure every 15-minutes)**
  - **Fluxes calculated as 3-min CH_4 and CO_2 gas concentration change**
- **Measured corresponding environmental variables within the SPRUCE experiment at 30-minute intervals including: Air temperature, soil temperature (20-cm), and water table depths.**



CO_2

- 3 years growing season data
- Sparse 2022
- More comprehensive
- Split by PAR (night vs day)
- Seasonal pattern of nightly efflux, daytime uptake
- Obvious response to temperature & eCO_2

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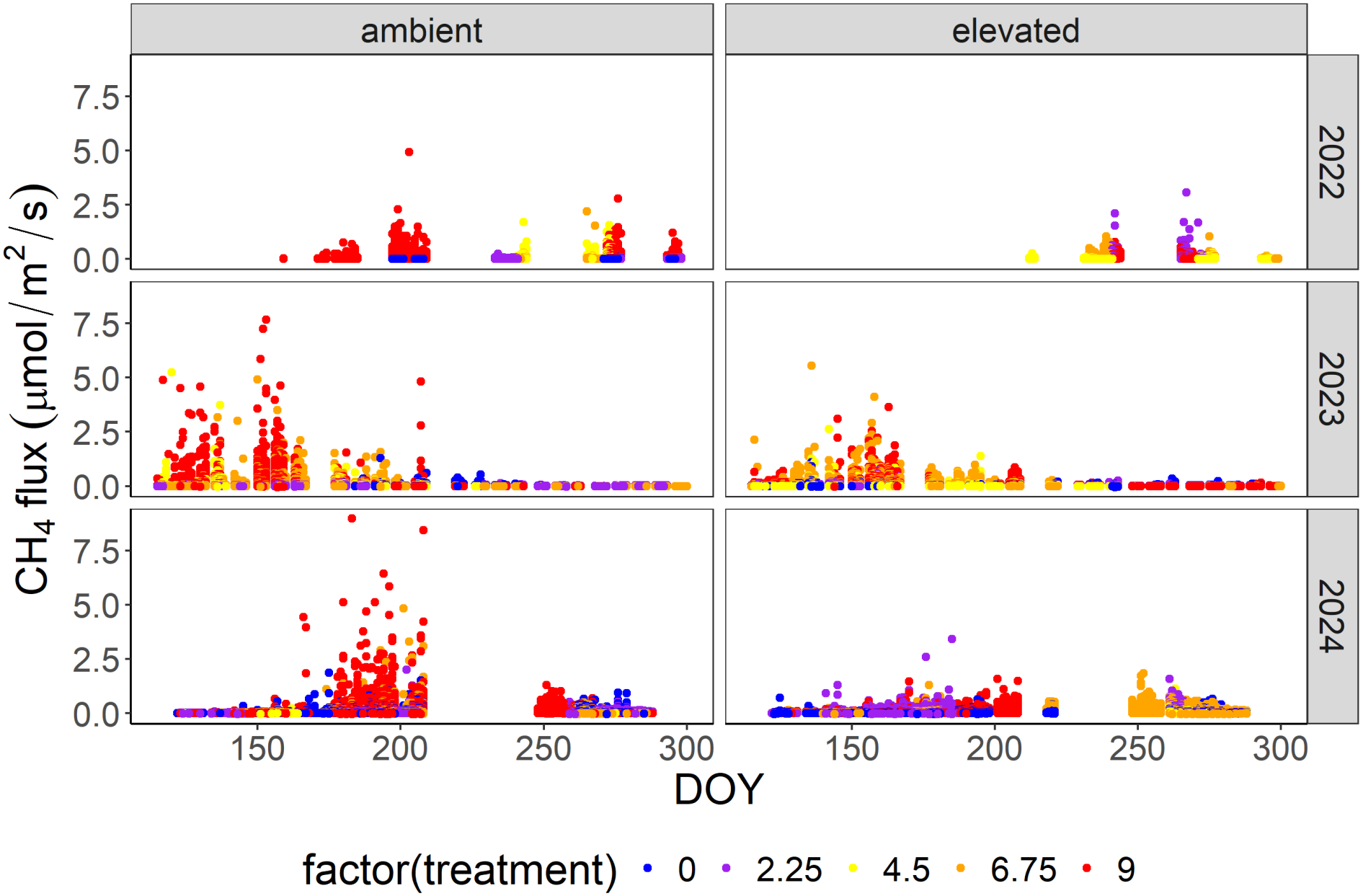
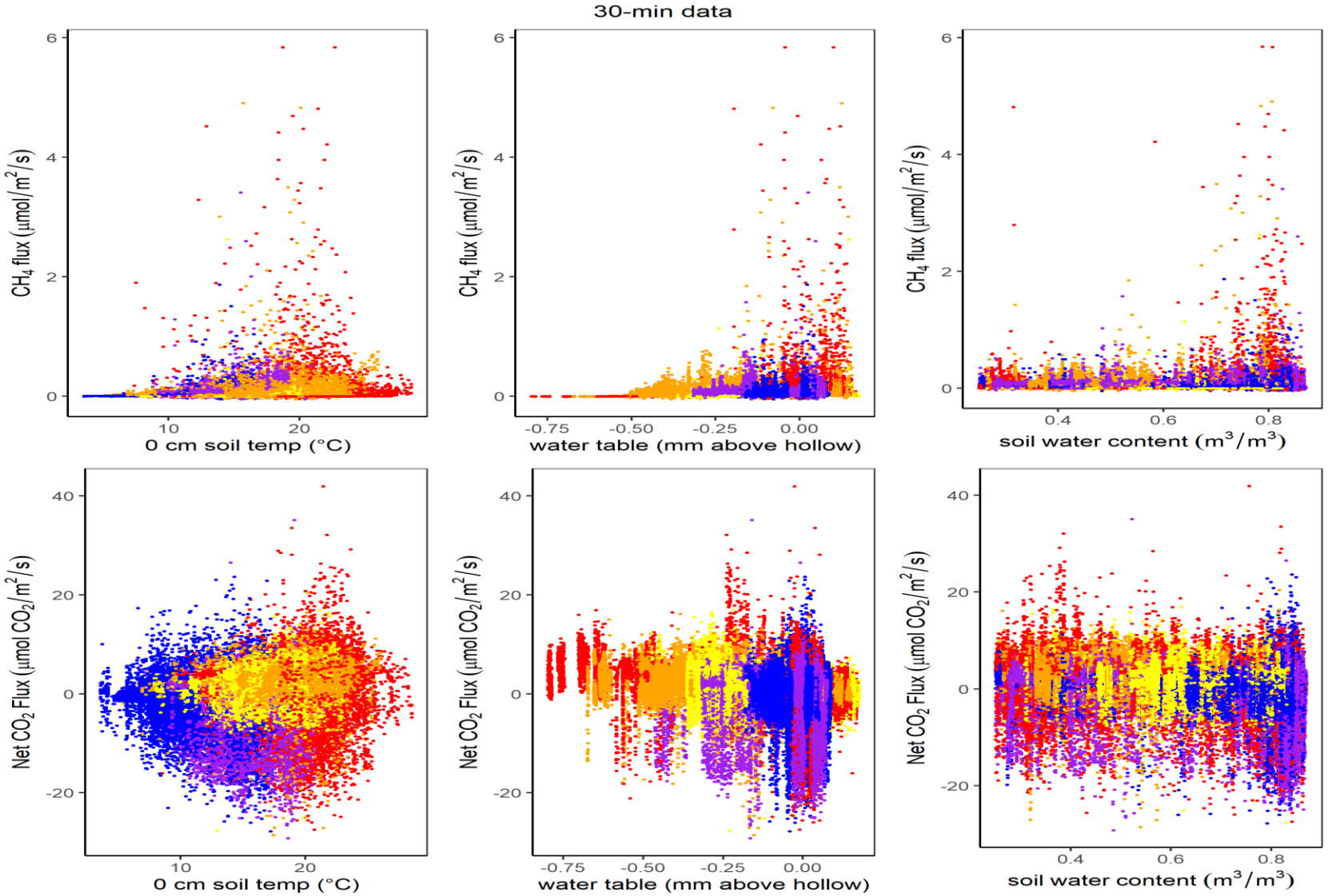
Methane

- 2-years of growing-season data
- Most fluxes are small-scale (<100 nmol/m^2/s)
- Larger flux events increased in some experimental plots



Environmental Variable Correlations



- Comparison with 30-min environmental variables (SPRUCE data stream)
- Probe responses to variables most important to CH_4/CO_2 flux
- Soil temperature
- Water table
- Soil moisture

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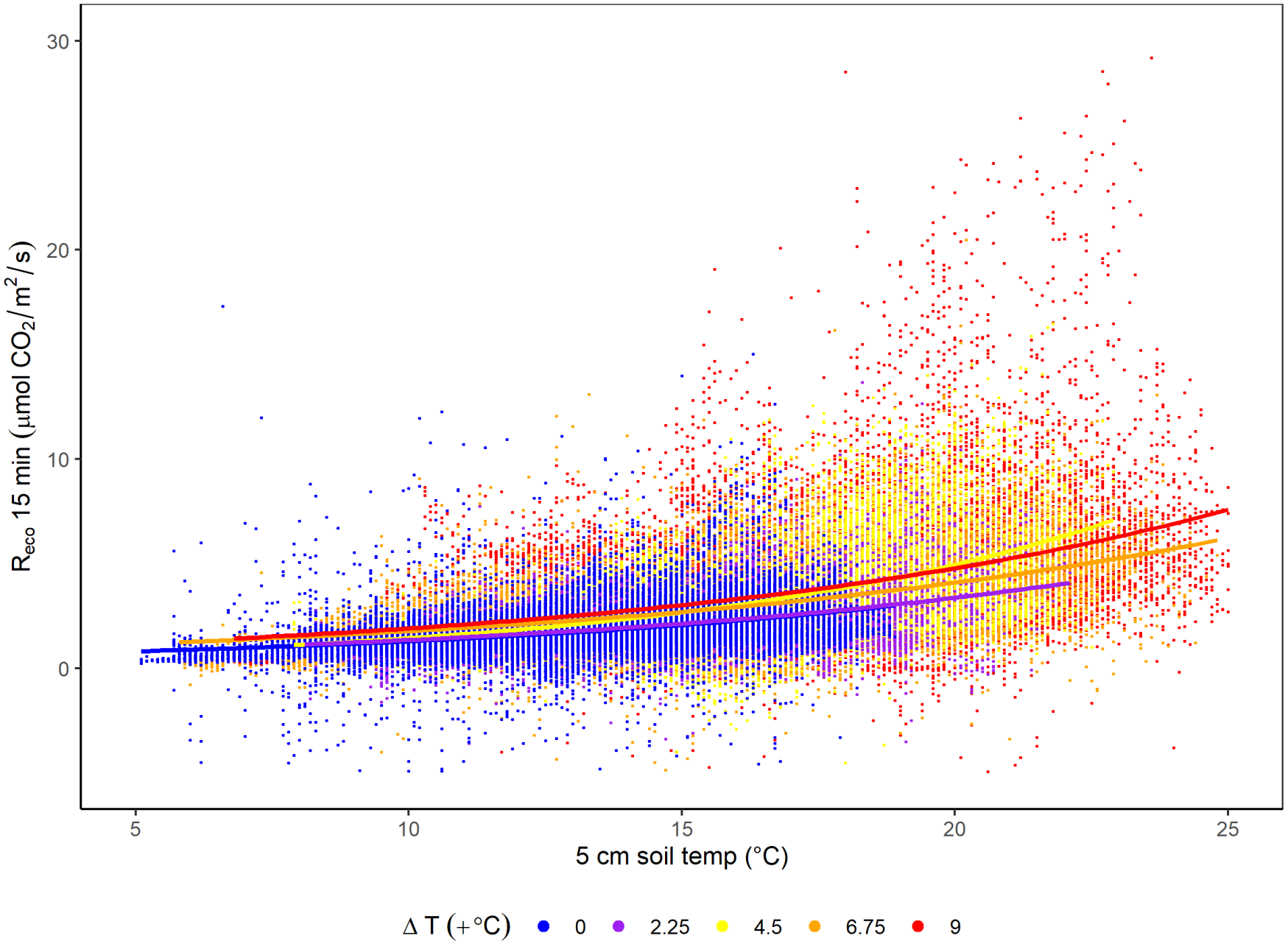
Q_{10}

- PAR <30 (nightly) CO_2 flux
- Fit Q_{10} nonlinear equations

$$R_E = BASE \times Q_{10}^{(T_X - T_{ref})/10)}$$

TREATMENT (+°C)	Q10 CO_2	Base @ 15°C CO_2	p-val
ALL	2.85	2.65	<.001
+0	2.71	2.07	<.001
+2.25	2.50	2.13	<.001
+4.5	3.44	2.67	<.001
+6.75	2.31	2.70	<.001
+9	2.47	3.02	<.001



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Methane: Q_{10} @ 20-cm soil temp + WT

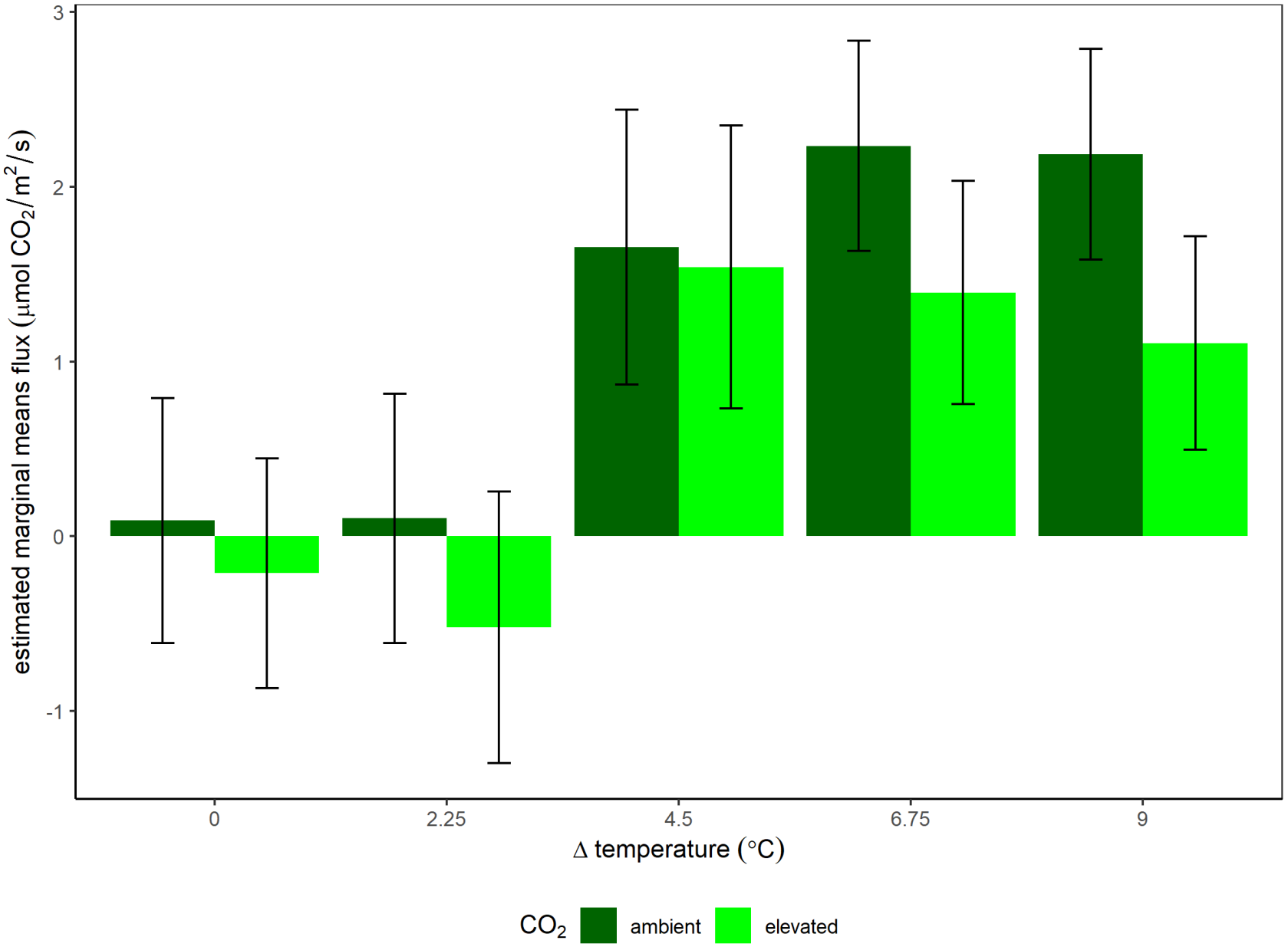
$$CH_4 = BASE \times Q_{10}^{(T_x - T_{ref})/10)} \times (WT_{frac})$$

$$WT\ frac = WT \times a+b$$

	METHOD	Q10 CH_4	Base @ 15°C CH_4	a	b
Hanson et al. 2016	LARGE CHAMBER	6.3	0.179	-0.002	0.624
This study	SMALL CHAMBER	8.3	0.029	-0.002	1.149

Net Flux-24 hr

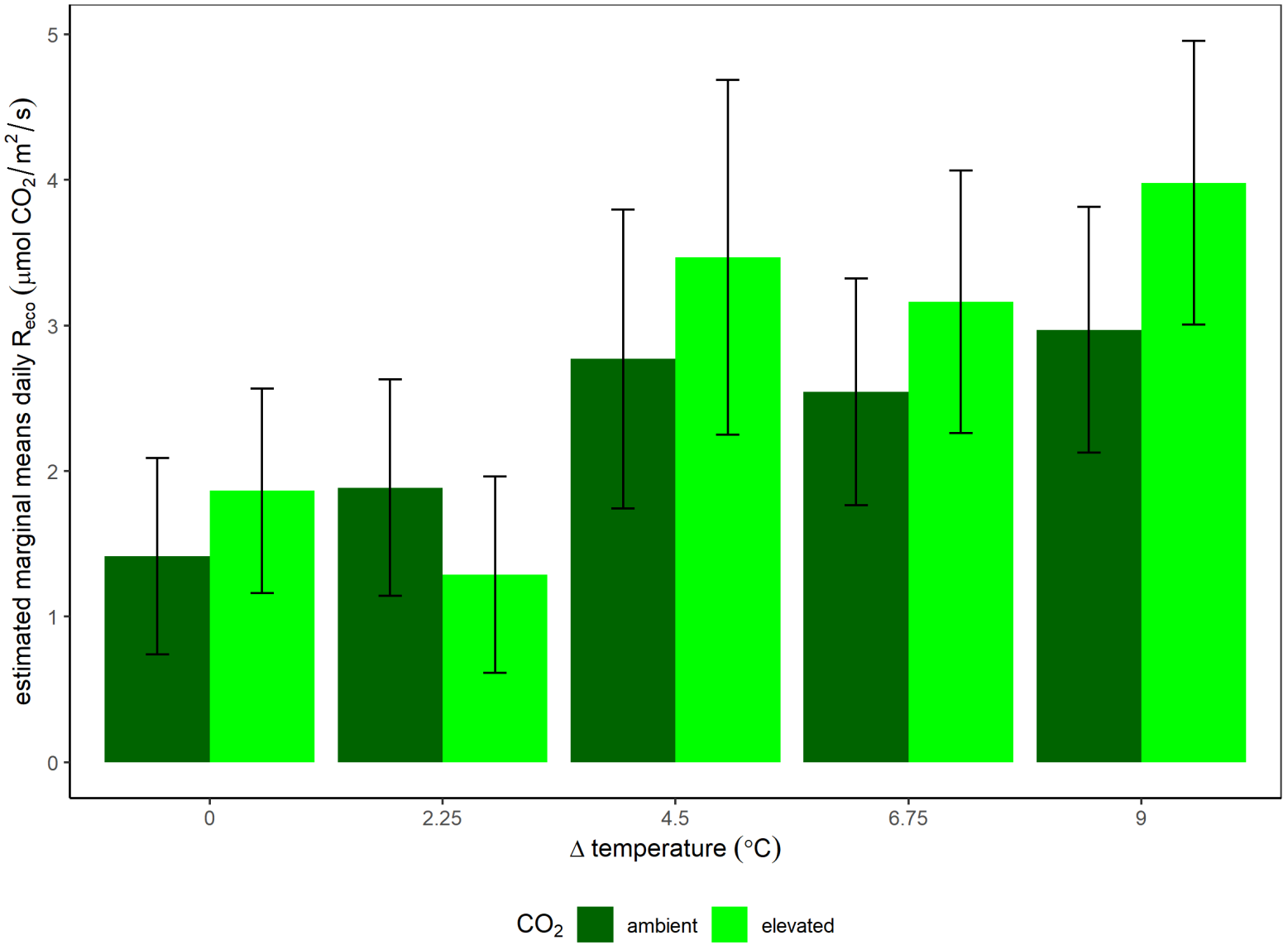
- Estimated marginal means
  - Model-based predictions of average response variable for factors by category
- Daily 24-hour period flux
- Net daily balance
- Shift to significant CO_2 source above 2.25°C



Respiration (night)

- PAR <30 (nightly) CO_2 flux
- Ecosystem respiration (R_{eco})
- Significant increase with temperature
- Reflective of the Q_{10}
- Highlights R_{eco} cause for shift above 2.25°C

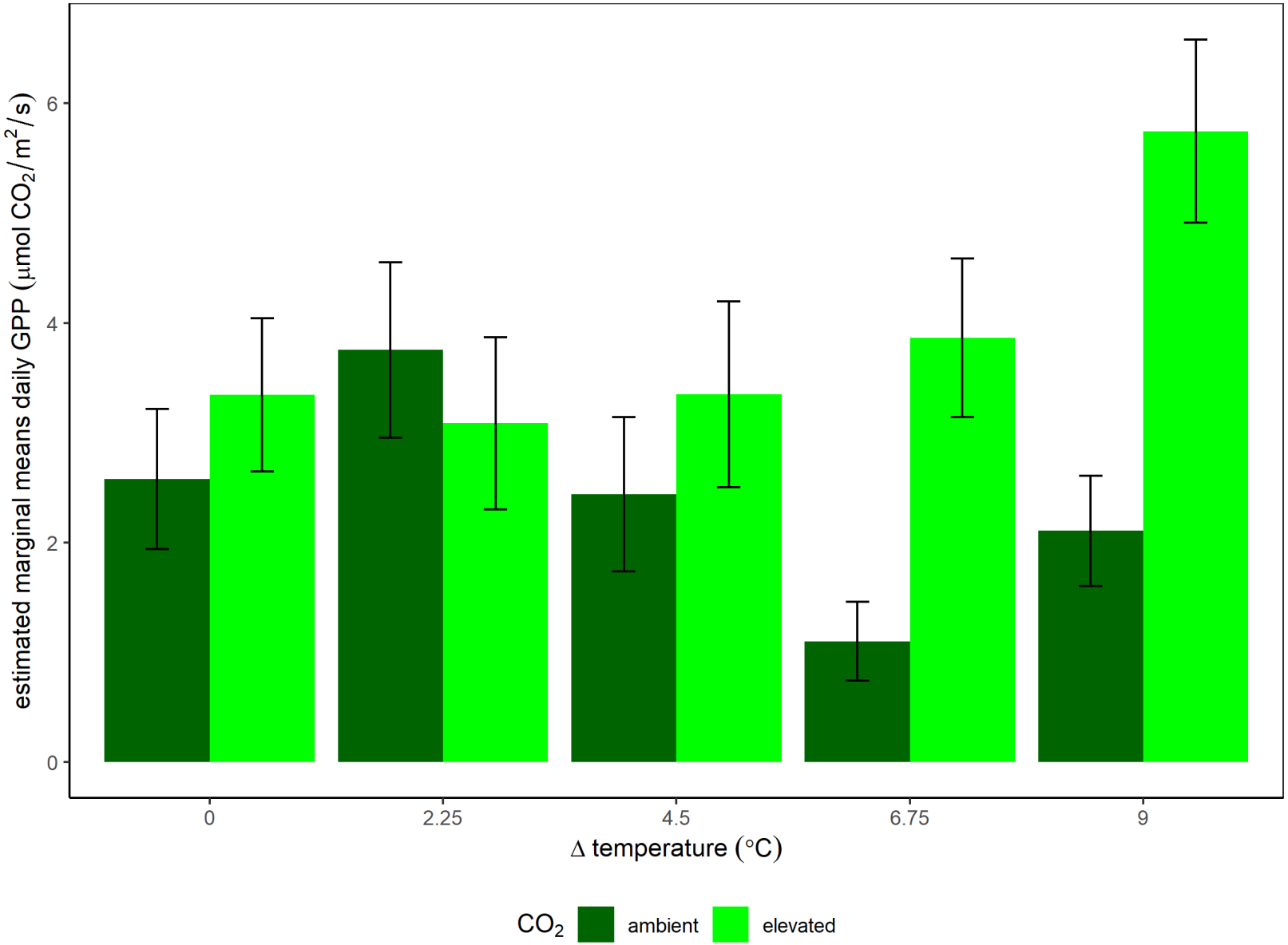
- Calculated nightly fluxes in 24-hour period for estimation of gross productivity:



Net-R_{eco} = daily gross primary productivity

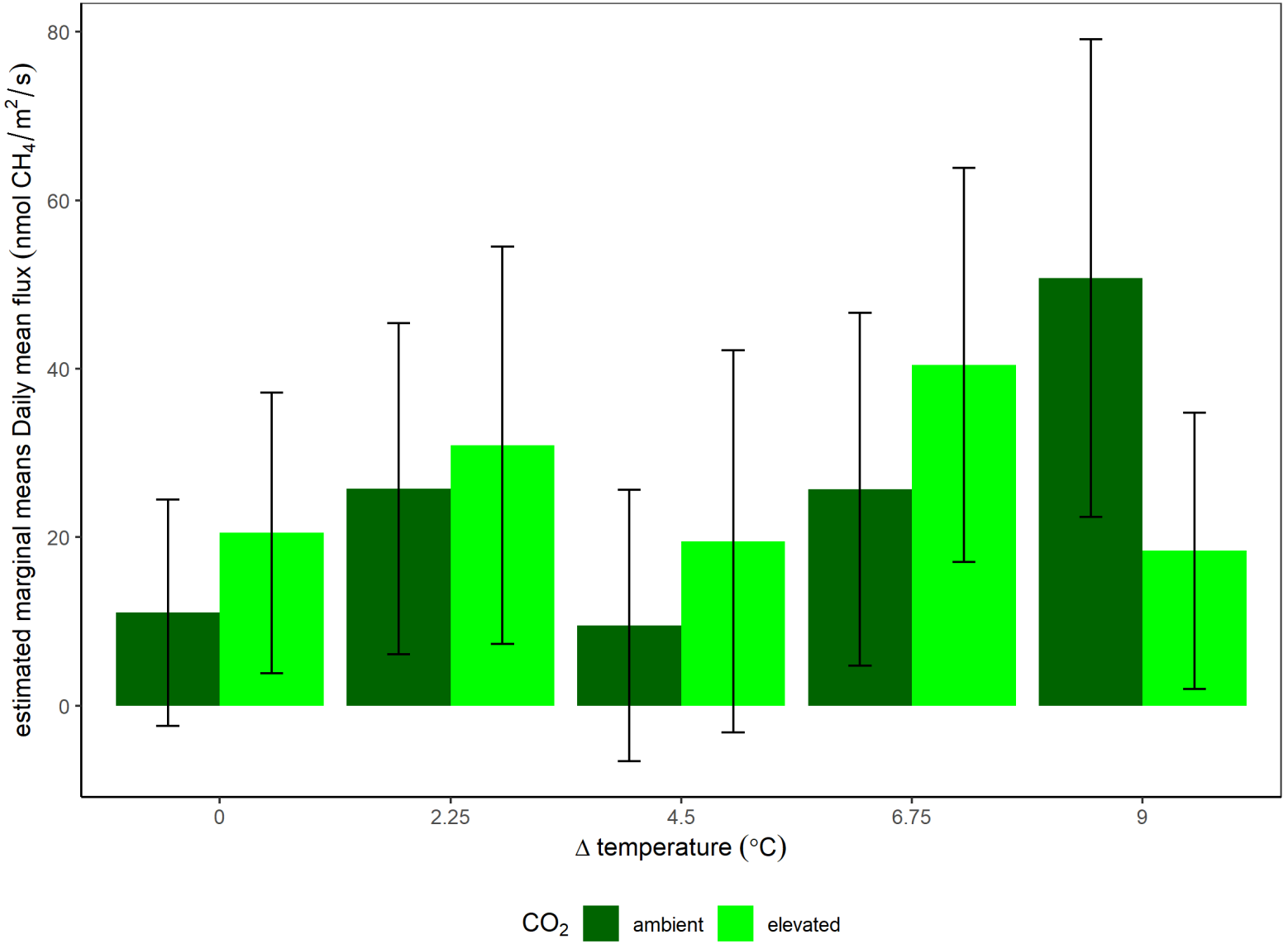
Gross primary productivity

- Significant differences above 4.5°C
- Ambient CO_2
  - Primary productivity lower or no change
- eCO_2
  - Primary productivity increased



Methane 24-hr

- No significant difference among the treatments
- Dominated by small-flux events (<100 nmol/m^2/s)
- Large-flux events more common in heated plots (>100 nmol/m^2/s)



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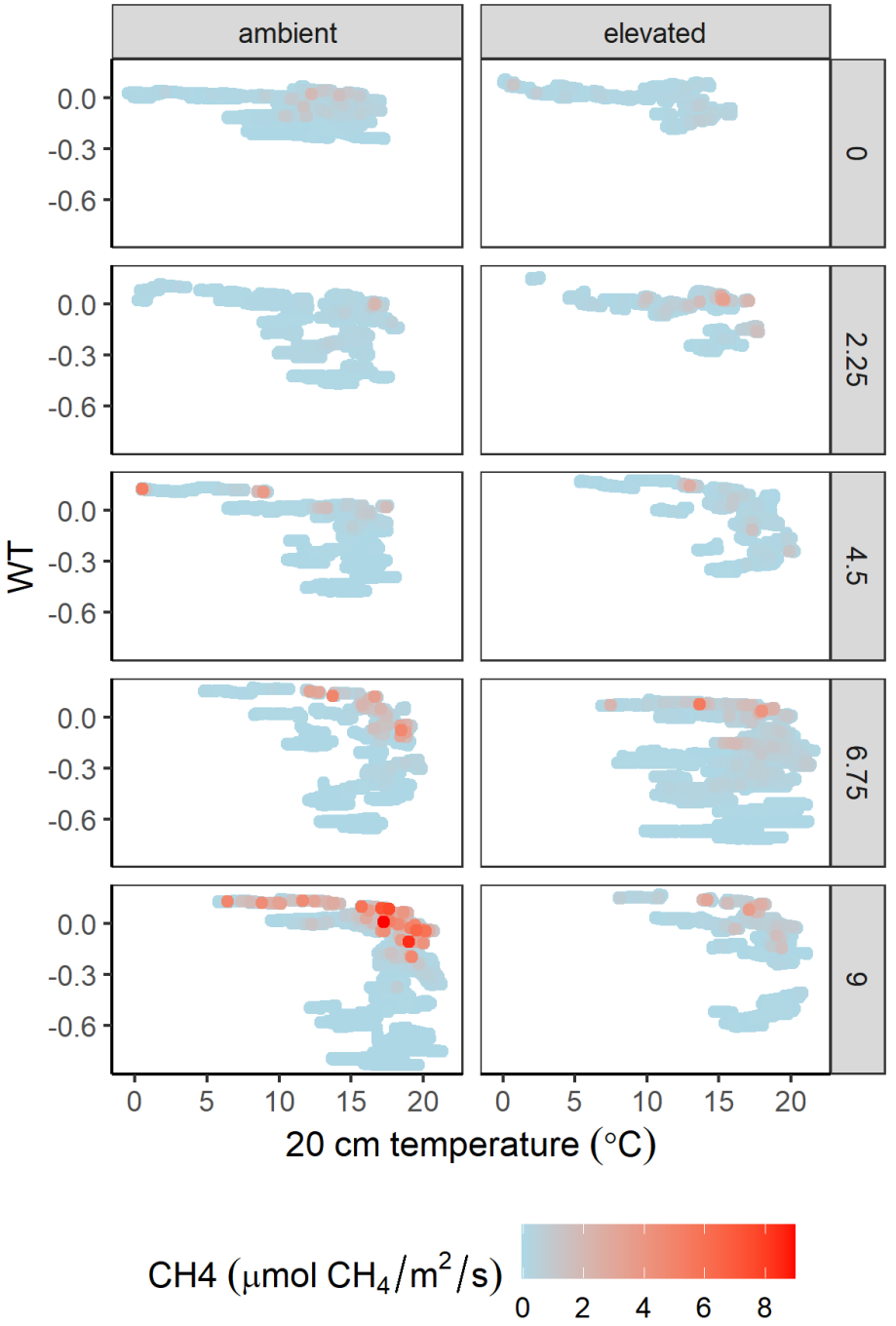
Water table vs Temp: CH_4

- Water table driven methane flux
- Temperature driven methane flux
- Water table – Temperature
- “hot spot” envelope
- Key environment when fluxes increase (>100 nmol/m^2/s)



Summary of key findings

- **Methane flux:**
  - Dominated by low-concentration background fluxes (<100 nmol/m^2/s)
  - Increase in response to temperature & water table height.
    - New WT term- Q10 fit
  - Lack statistical significance across large data time-series among the categorical variables
- **CO_2 flux:**
  - Significantly increased CO_2 efflux (sink to source) shift above 2.25°C
  - Driven by increased respiration (Q_{10})
  - eCO_2 Increased primary productivity: CO_2 fertilization effect
  - Increased Moss-shrub GPP not enough to offset increased R_h

2025 season:

- Final measurement year
- R_h???
- Dry biomass quantification for flux normalizing

- Suggestions??

Green Plot

Clipped Plot

Biomass harvested in10 of 20 Eosense collars Sept-2024