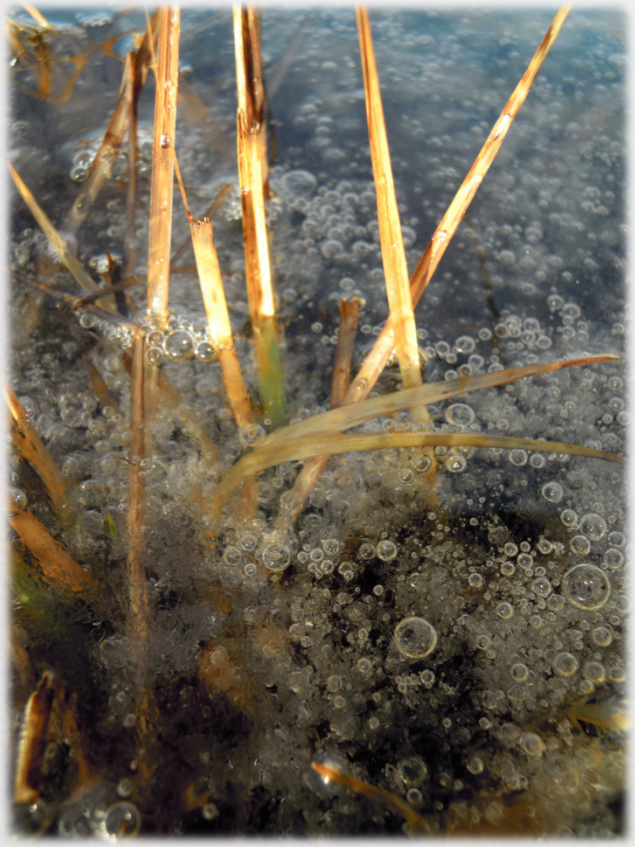
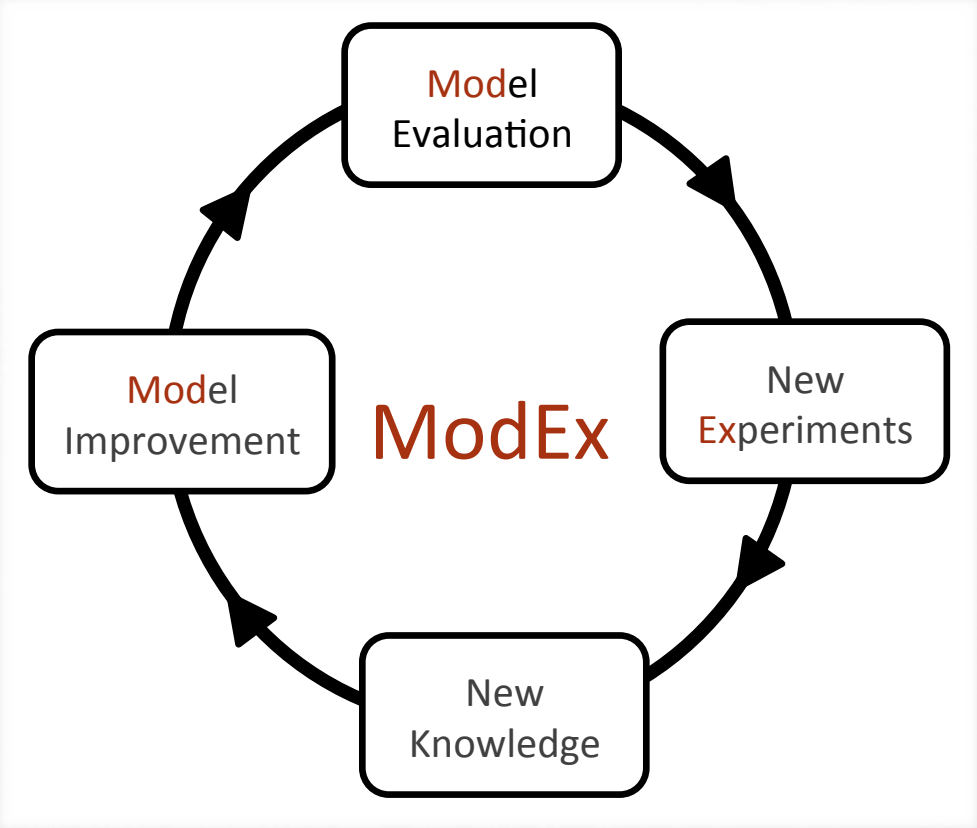
Methane processes in the ModEx framework

bridging the measurement—model divide





Lydia Smith • NGEE-Arctic All-Hands meeting • December 13, 2014

Research questions

1. How do CH_4 production pathways vary across spatial and temporal gradients?
2. How do these subsurface processes relate to net GHG fluxes?

Spatial distribution of net CH_4 fluxes, gross CH_4 processes, and underlying controls

Image courtesy of Baptiste Dafflon

Methods

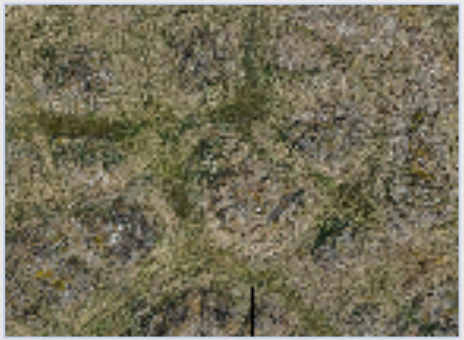
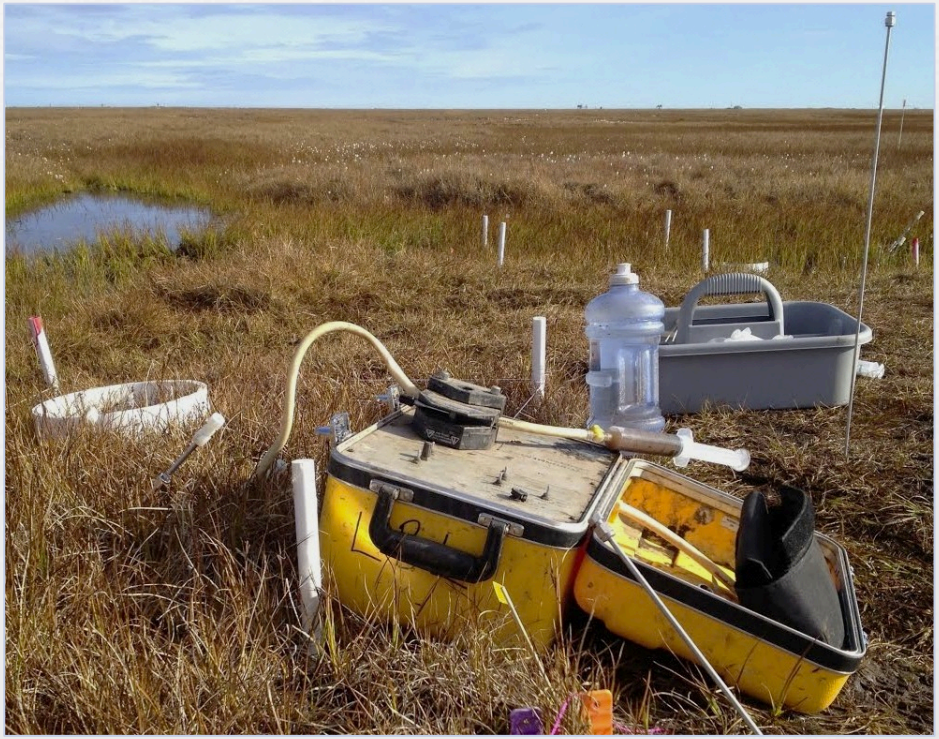
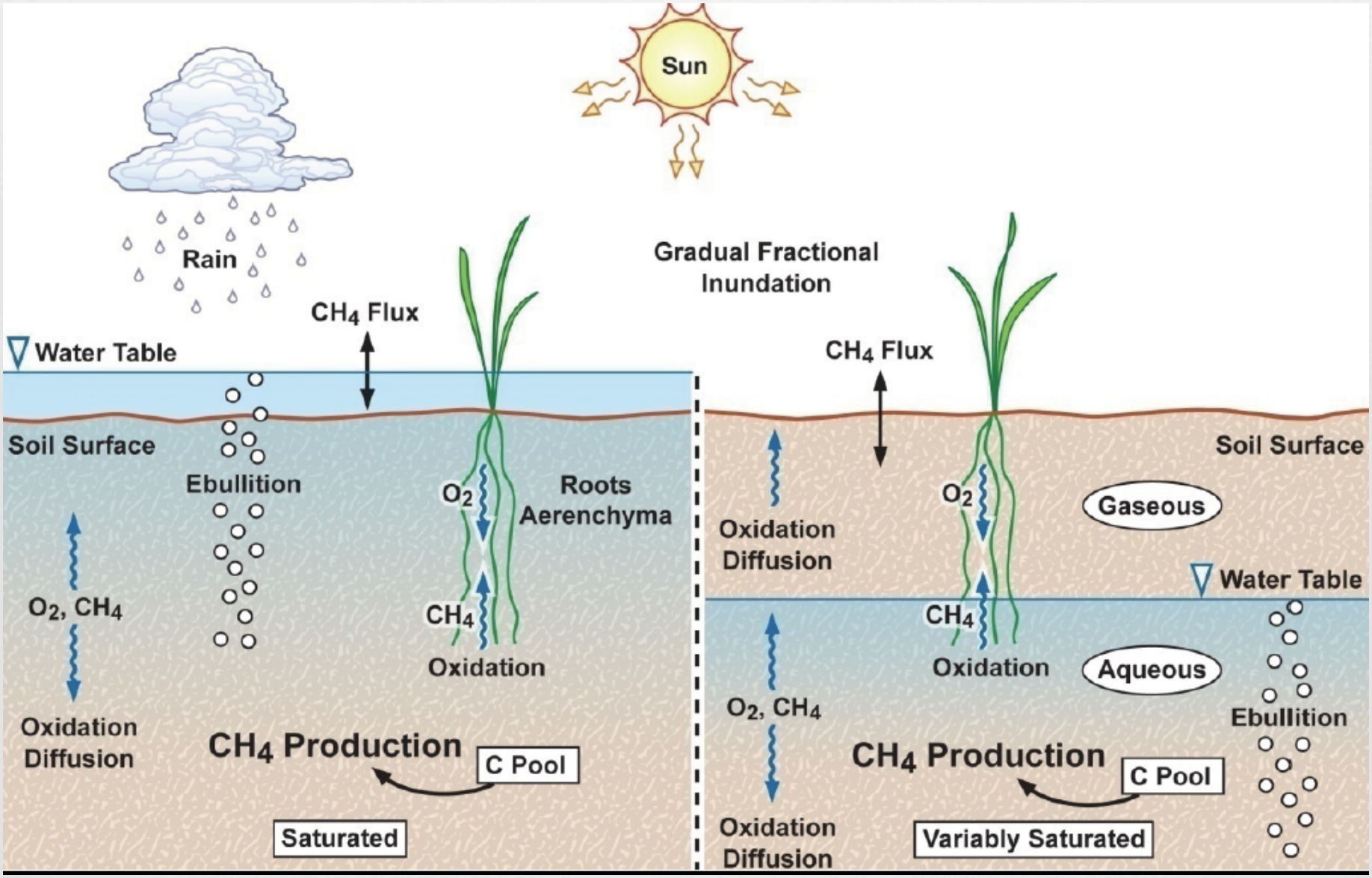


Image from Baptiste Dafflon



Methane processes



CH_4 flux at the landscape scale

Comparing CLM predictions and surface CH_4 flux measurements

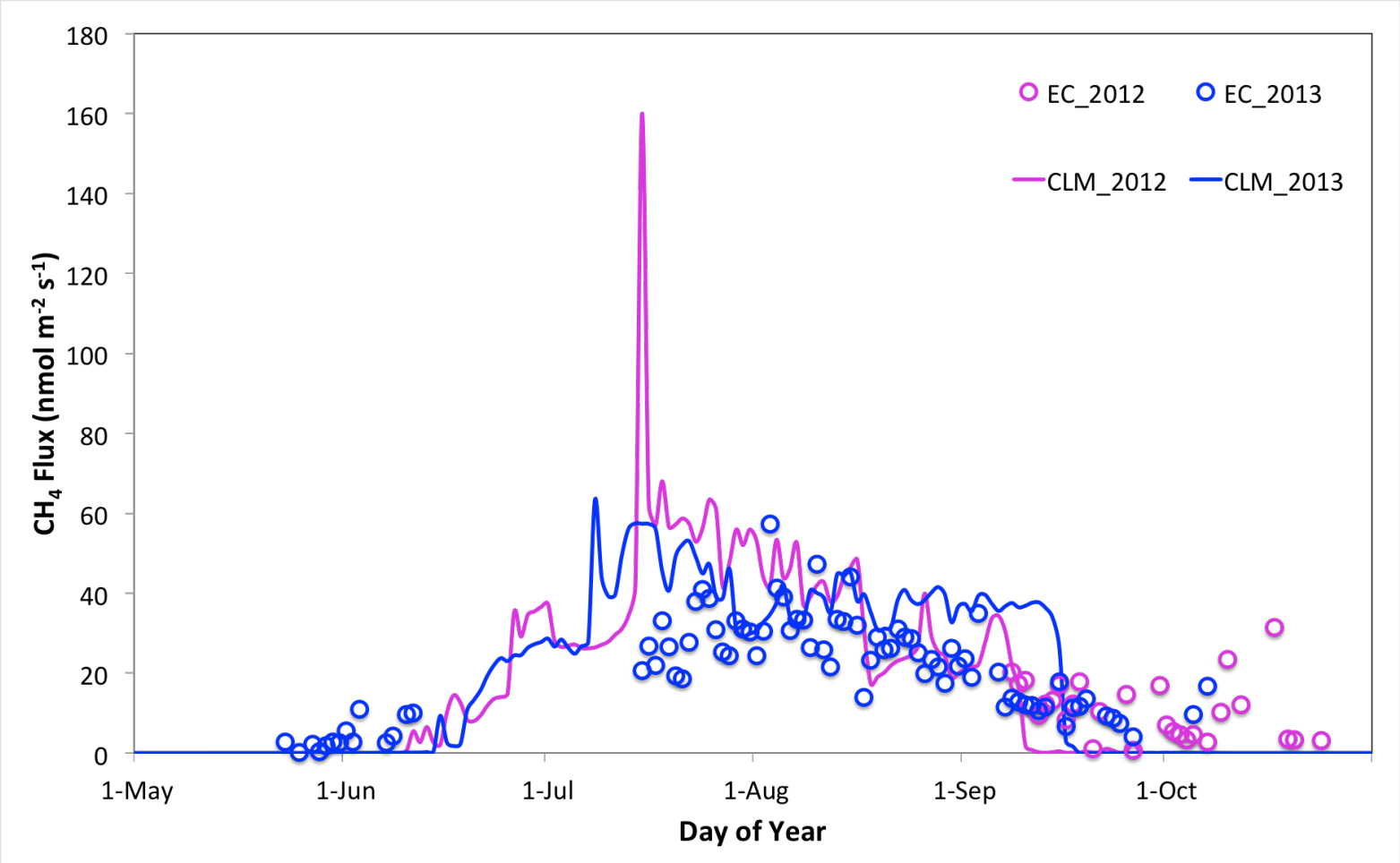
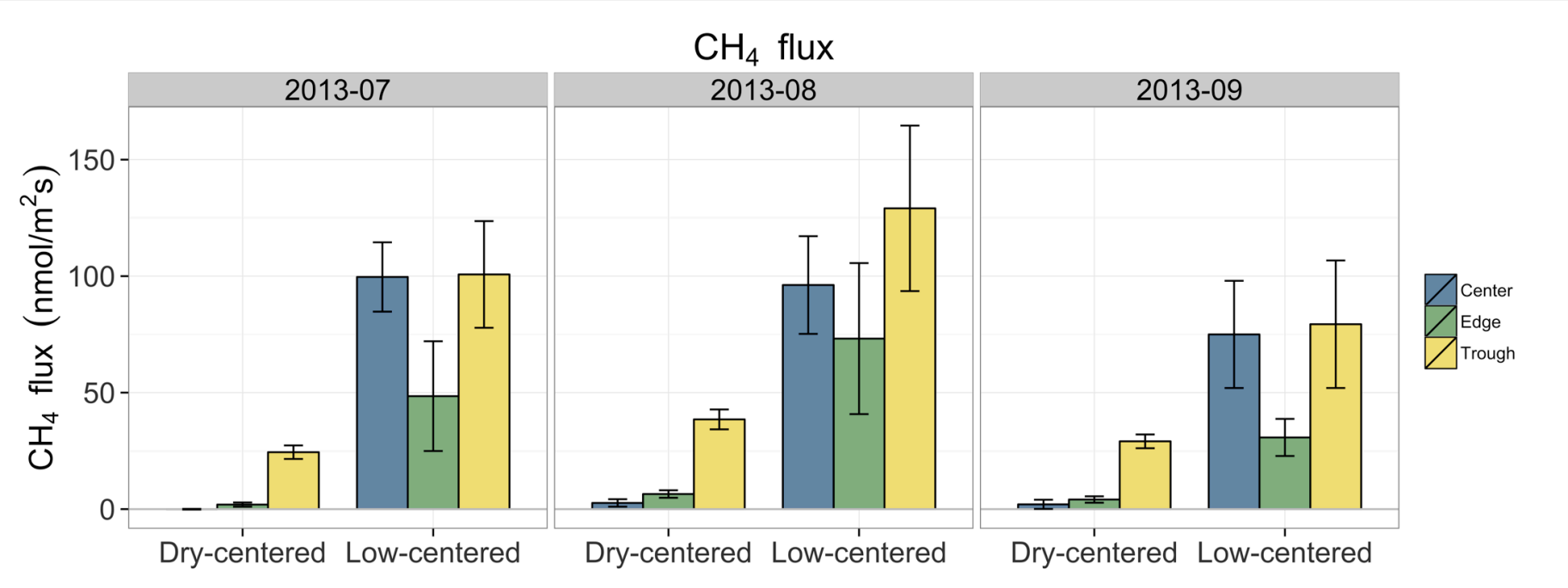


Figure from Xiyan Xu and Naama Raz Yaseef

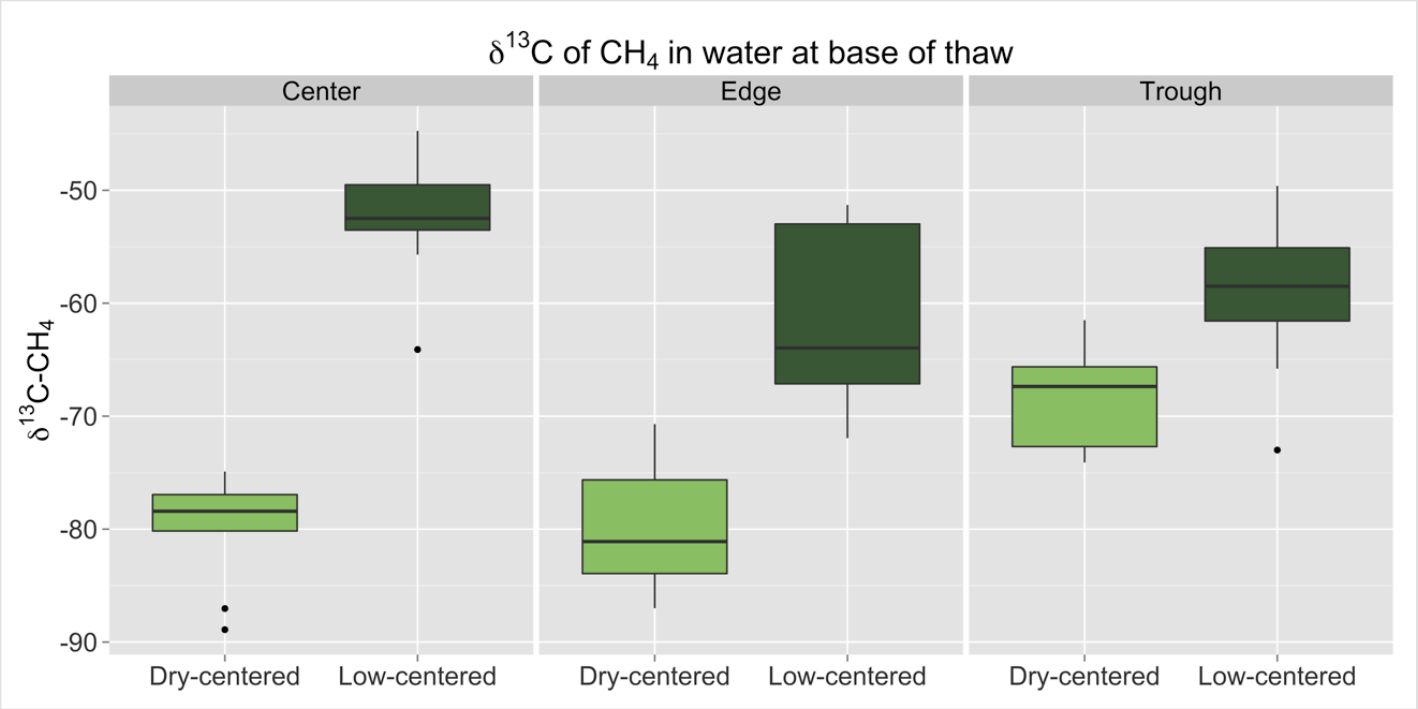
CH_4 flux at the profile scale

Soil moisture and temperature don't tell the whole story.



^{13}C evidence of methanogenic pathway

Stable isotope patterns resemble those of CH_4 fluxes



acetoclastic methanogenesis

$\delta^{13}C$= -50 to -65 ‰

↑

↓

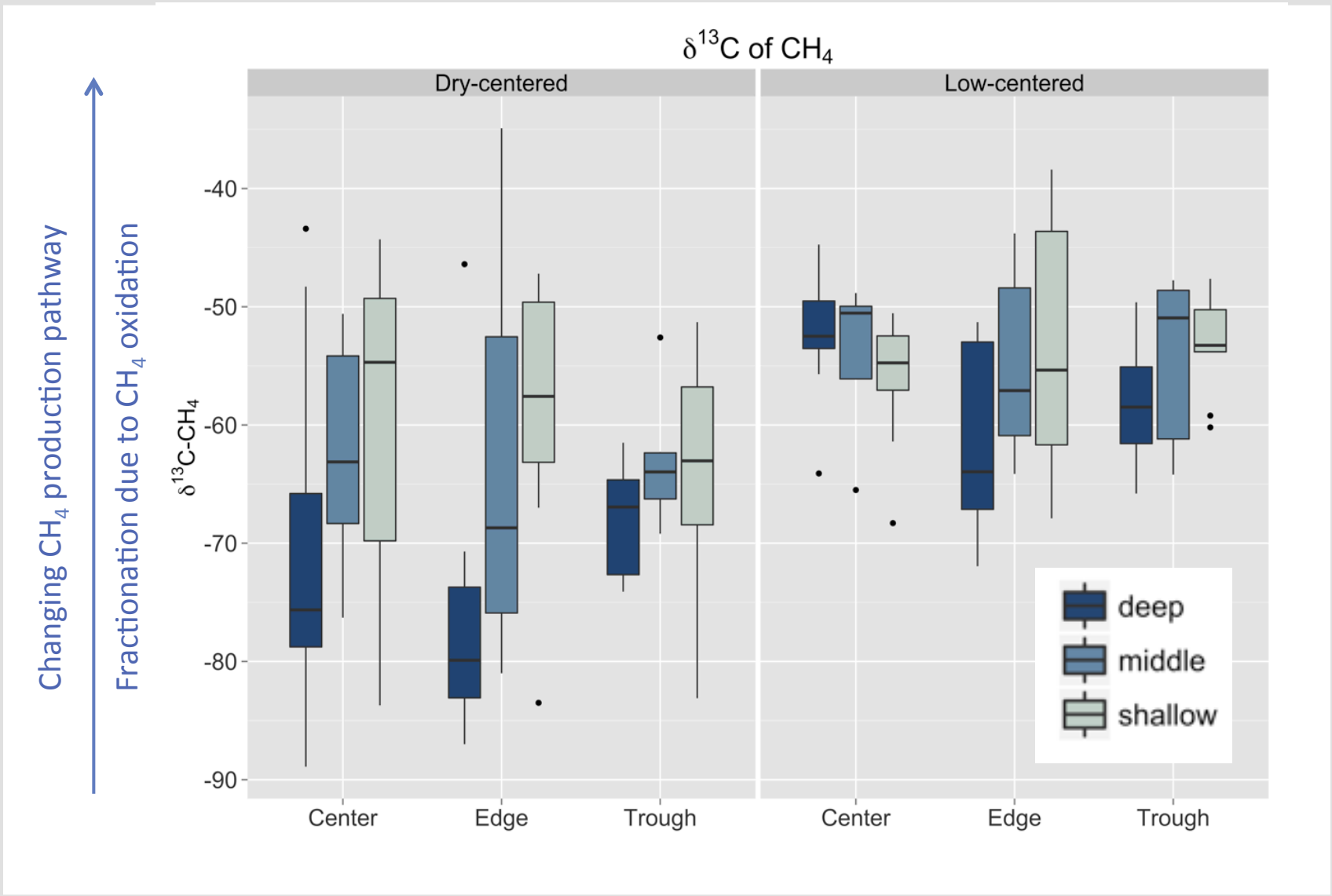
hydrogentrophic methanogenesis

$\delta^{13}C$= -60 to -110 ‰

Distinct methane production pathway between the two polygon types

Higher lateral flow in dry-centered polygons

^{13}C profiles



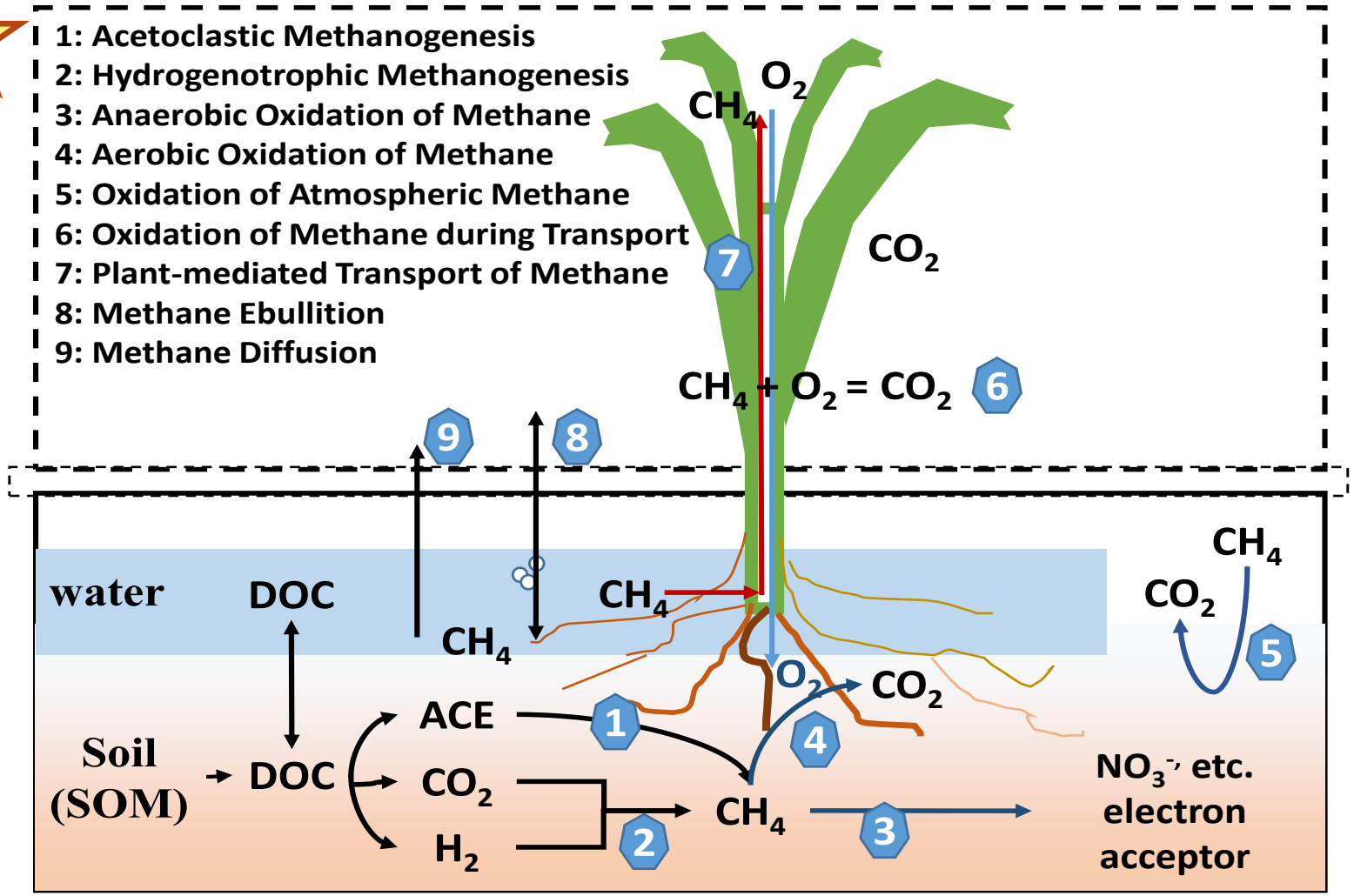
ModEx: bridging measured and modeled metrics

	n	fCO_2-$_{OMdecay}$ (%)			fCO_2-$_{meth}$ (%)			n	CH_4-$_{Trans}$			CH_4-$_{diff}$		
July														
Shallow	14	79.4	±	9.1	20.6	±	9.1	14	75.7	±	10.3	24.3	±	10.3
Deep	13	52.8	±	6.1	47.2	±	6.1	14	94.0	±	1.4	6.0	±	1.4
September														
Shallow	15	90.1	±	8.9	9.9	±	8.9	10	94.9	±	2.9	5.1	±	2.9
Deep	15	100.6	±	12.7	-0.6	±	12.7	8	91.2	±	2.9	8.8	±	2.9

Table 1. The fraction of deep subsurface CO_2 produced from respiration (fCO_2-$_{OMdecay}$) and from methanogenesis (fCO_2-$_{meth}$) as a percentage of deep subsurface CO_2; and deep subsurface CH_4 lost by i) plant mediated transport and ebullition (CH_4-$_{Trans}$) vs. ii) diffusion (CH_4-$_{diff}$).

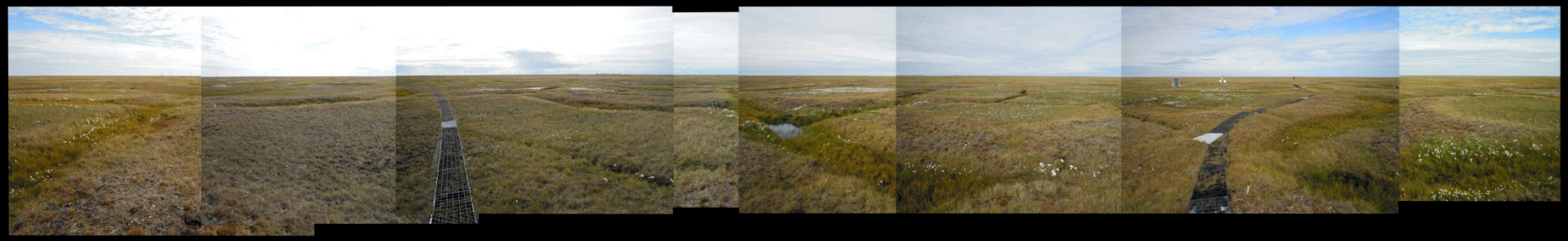
Throckmorton *et al.*, 2014. (Submitted to GBC):

ModEx: methane module



Key processes of CH_4 cycling (two CH_4 production, four CH_4 oxidation and three CH_4 transport processes contribute to the land surface net flux)

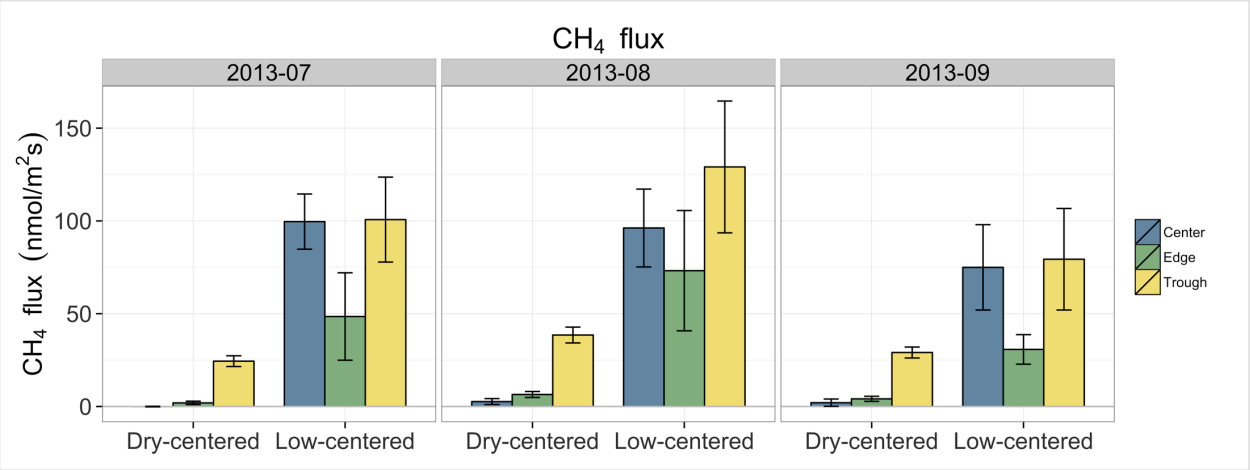
Figure from Xiaofeng Xu

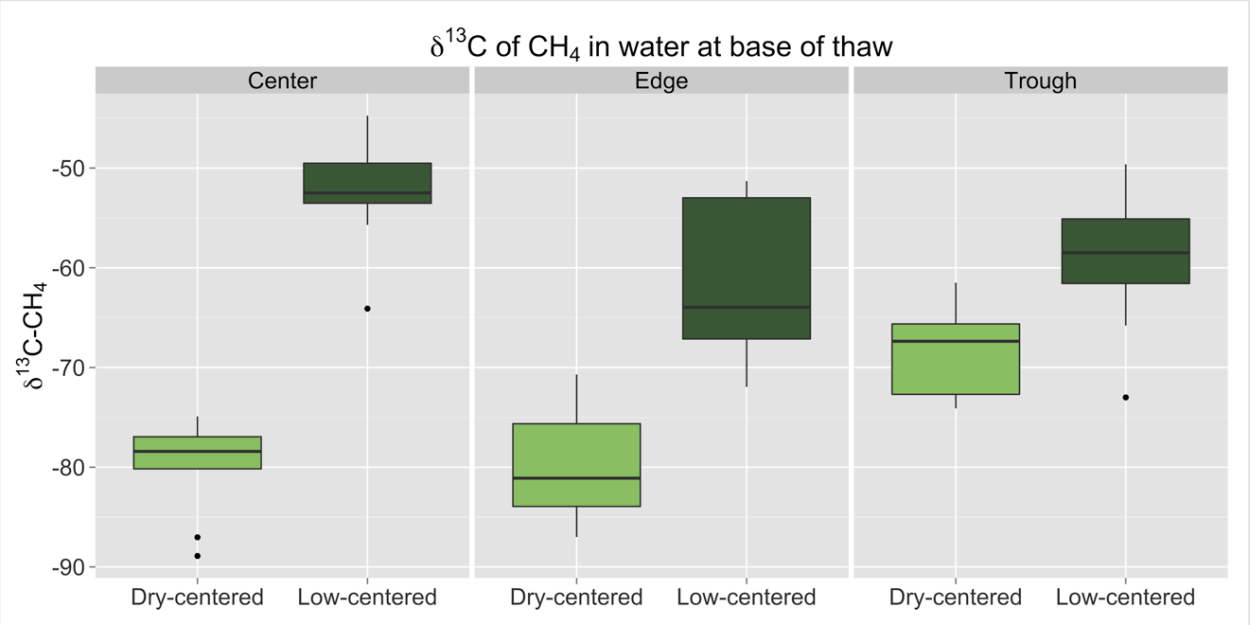


Summary

- Important linkages: geomorphology, geochemistry, CH_4 flux
- ModEx Challenges:
  - Gap between measured quantities and model metrics
  - Lateral flow
  - Microscale heterogeneity (production in microsites)
- Future prescriptions:
  - Comprehensive, co-located suites of measurements
  - Experiments to measure gross rates
  - Isotope tracer in models

Spatially-explicit mechanisms





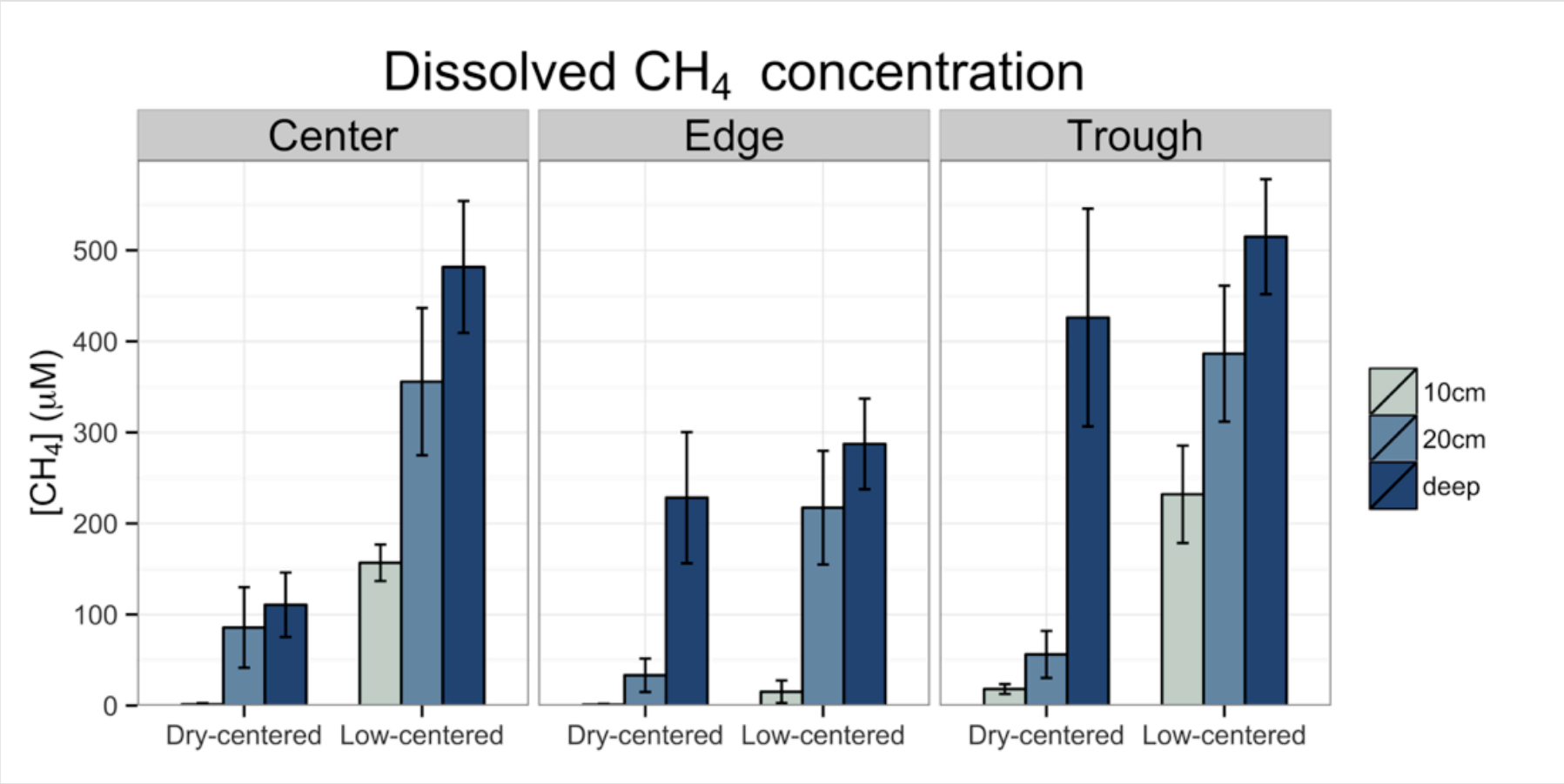
Functional differences between polygon types

Mechanism?

→ Geochemical differences: sulfate and DO

→ Lateral flow

Zonation scheme

Data: dissolved CH_4 concentrations

High CH_4 concentrations at depth in all polygon features