METHANE TRANSPORT DURING A FIELD-SCALE METHANE RELEASE

Mark Felice

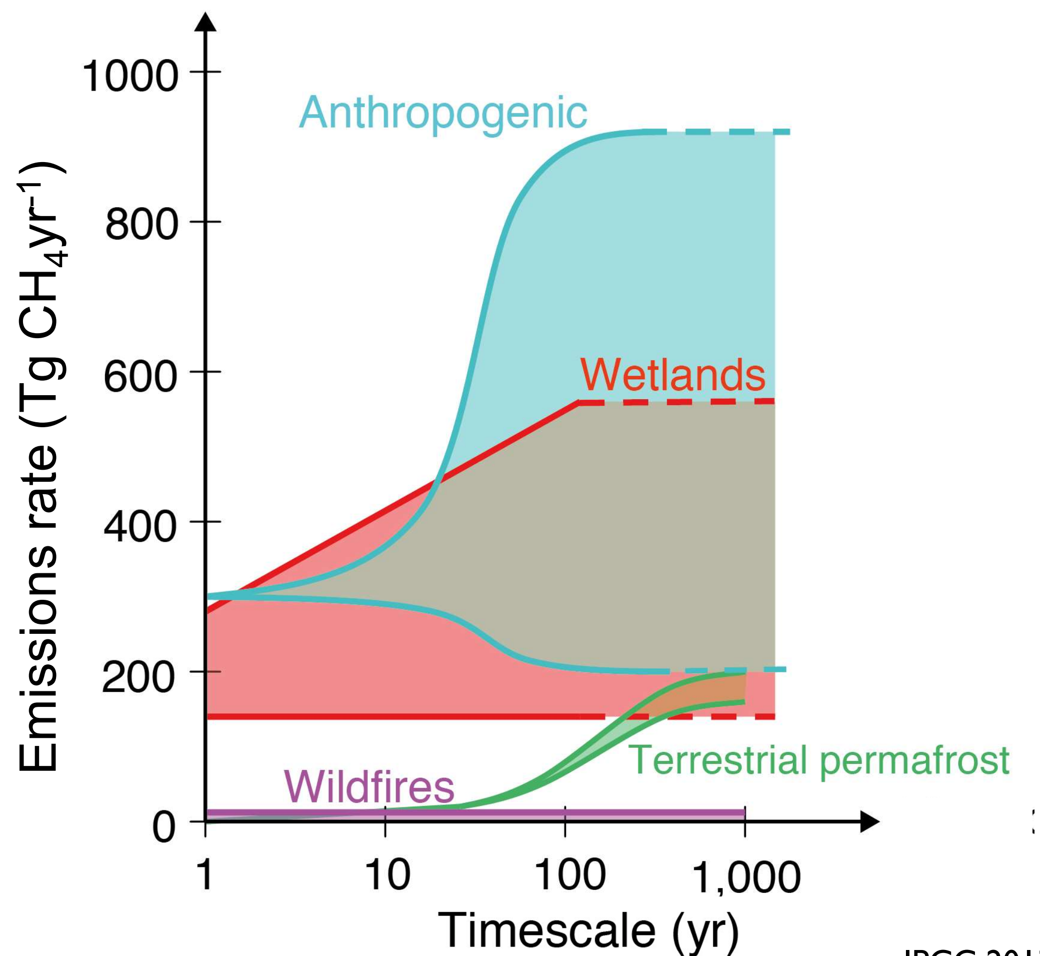
10/31/2019

ROADMAP OF TODAY'S PRESENTATION

- General background
- Research context
- Experiment overview
- Experiment results
  - Methane transport
  - Direct impacts on methanotroph communities
- Wrap up

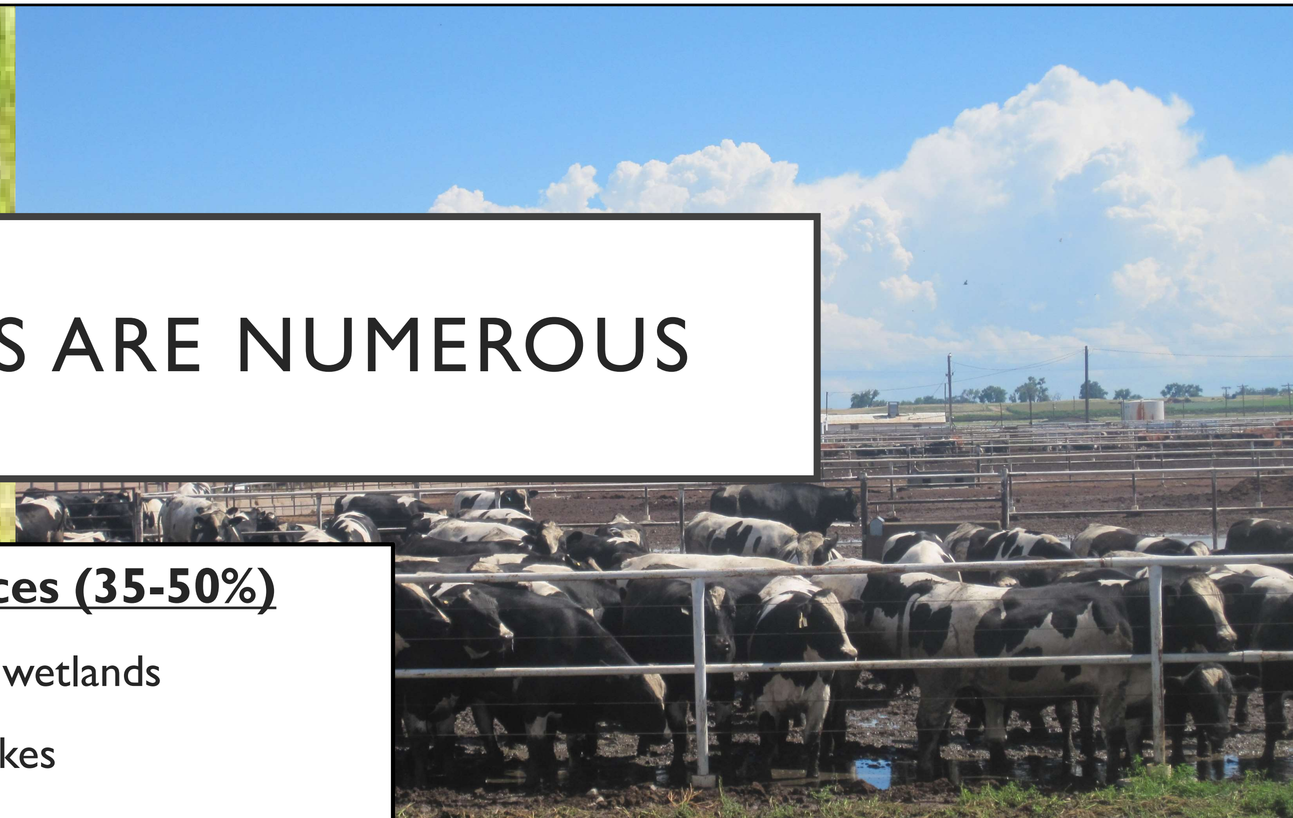
METHANE IS AN IMPORTANT GREENHOUSE GAS

- 2nd-most important greenhouse gas
- 28x more warming potential than CO_2
- Atmospheric levels ~ 150% of pre-industrial levels
  - Mainly anthropogenic
- Emissions expected to rise: How much?
  - Land-use change
  - Permafrost thaw
  - Peatland warming

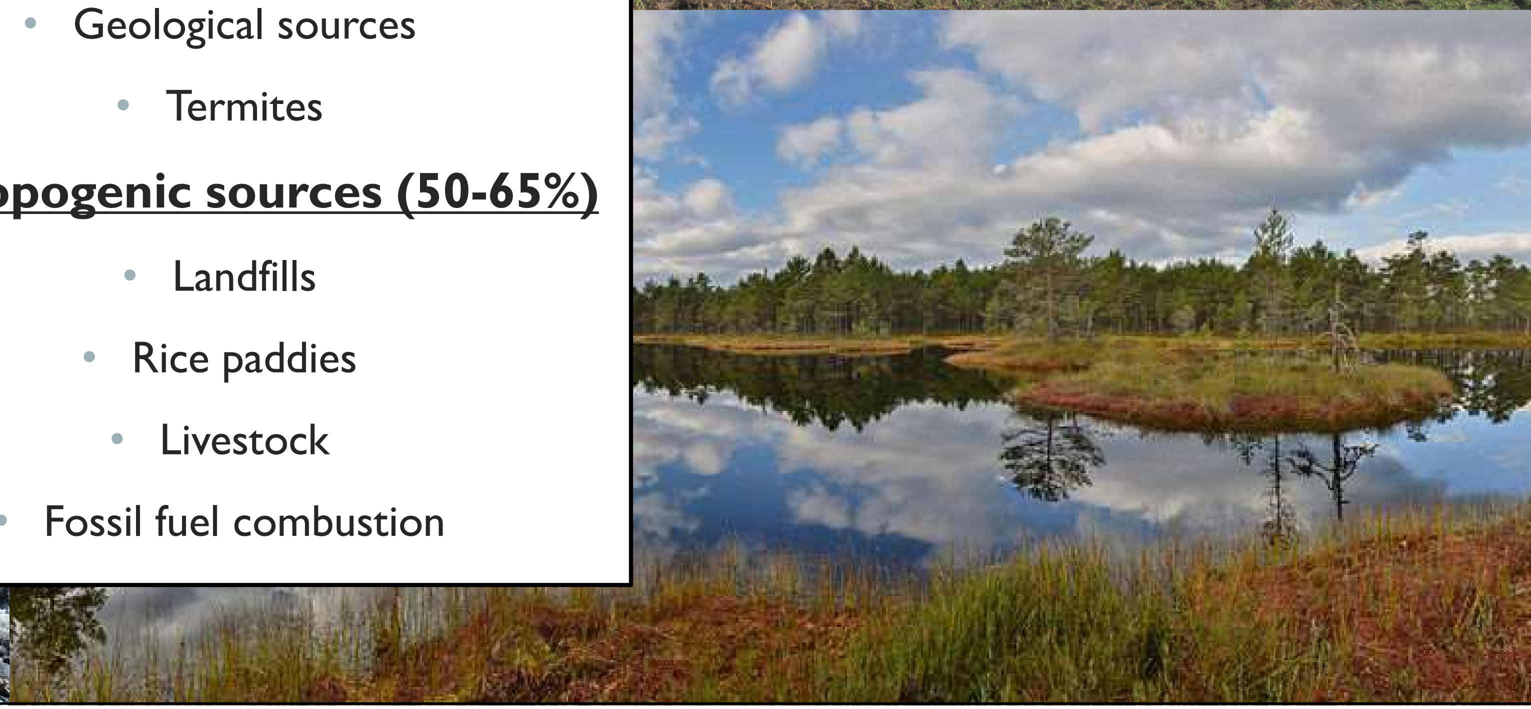


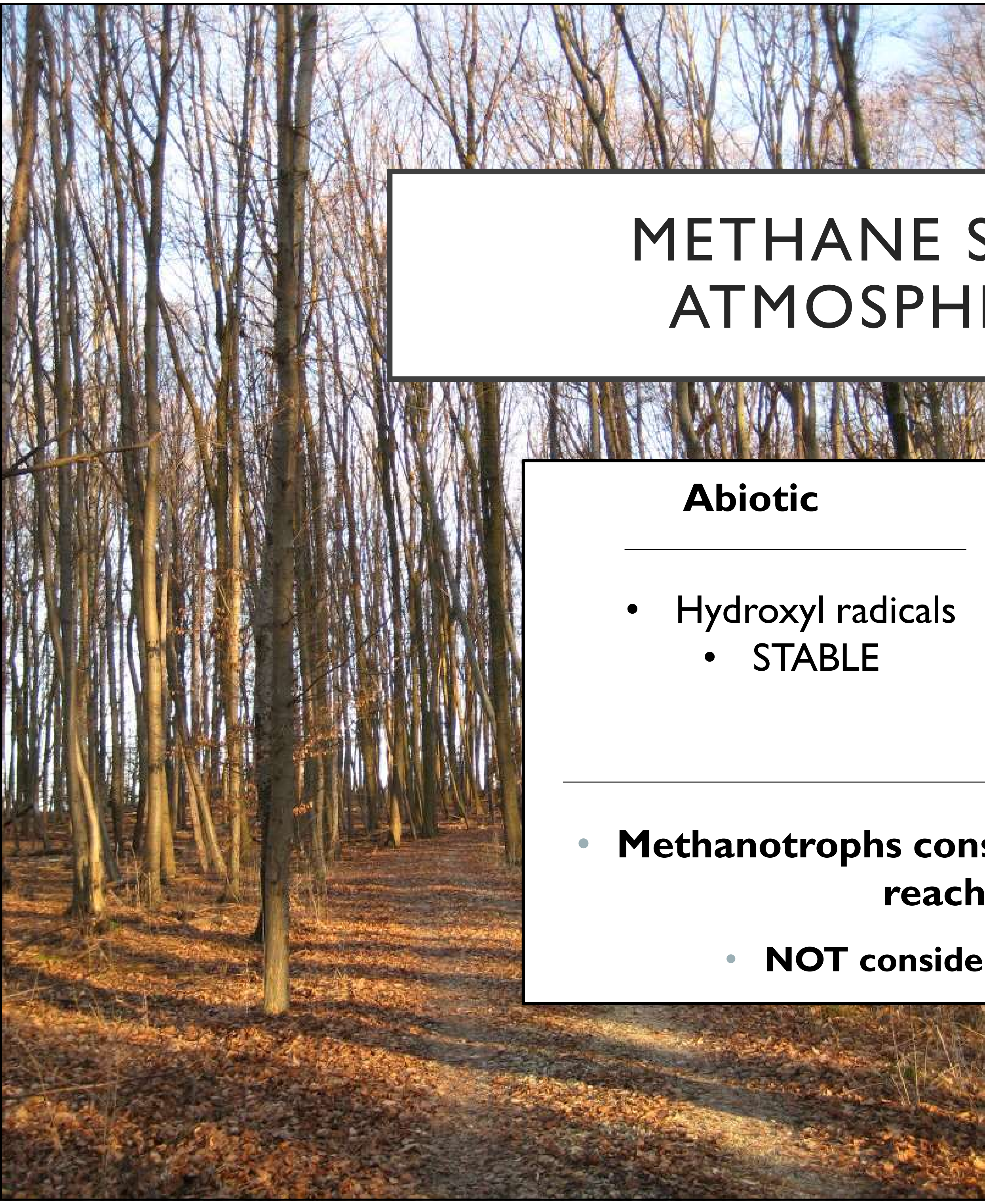
IPCC 2013

METHANE SOURCES ARE NUMEROUS



- **Natural sources (35-50%)**
  - Natural wetlands
  - Lakes
  - Geological sources
  - Termites
- **Anthropogenic sources (50-65%)**
  - Landfills
  - Rice paddies
  - Livestock
  - Fossil fuel combustion






METHANE SINKS CONSUME ATMOSPHERIC METHANE

Abiotic

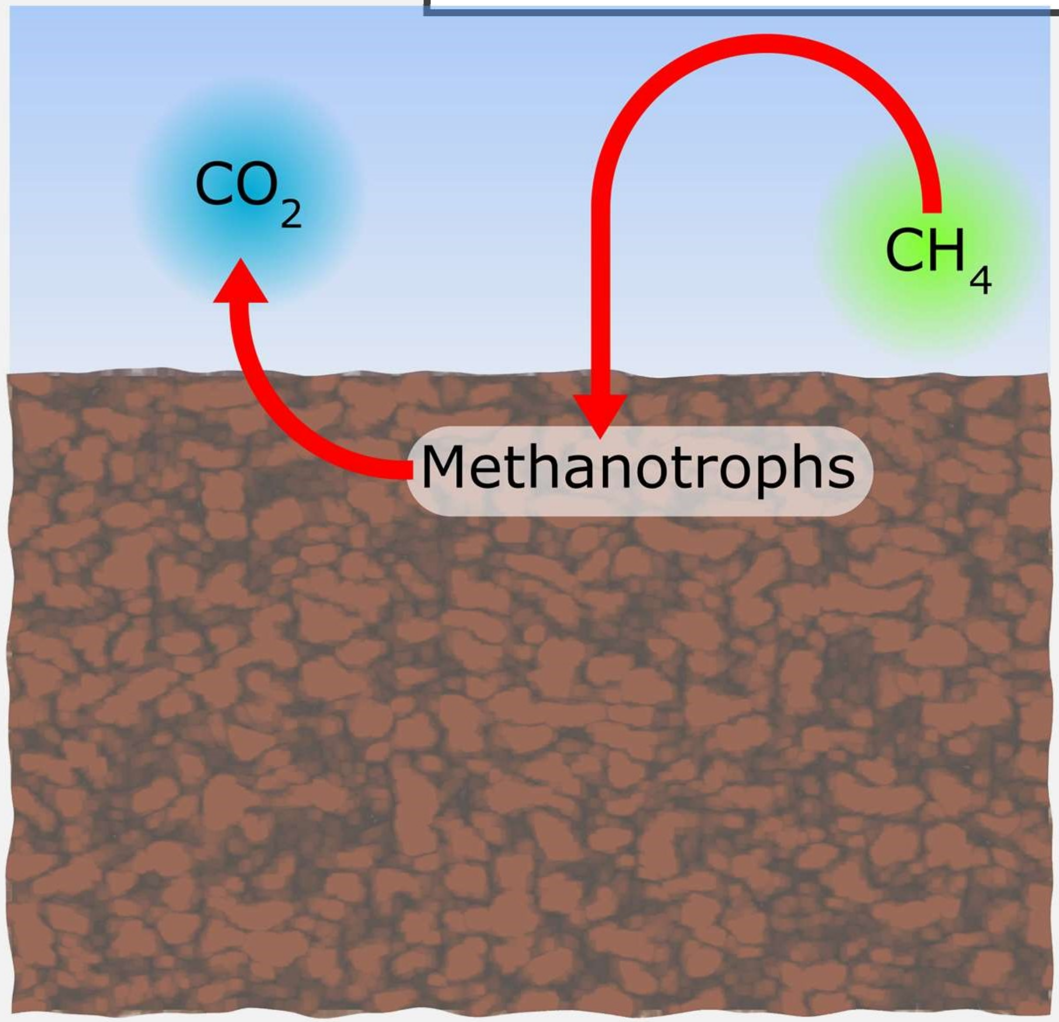
- Hydroxyl radicals
- STABLE

Biotic

- Methanotrophs
- 4% of global sink
- DYNAMIC

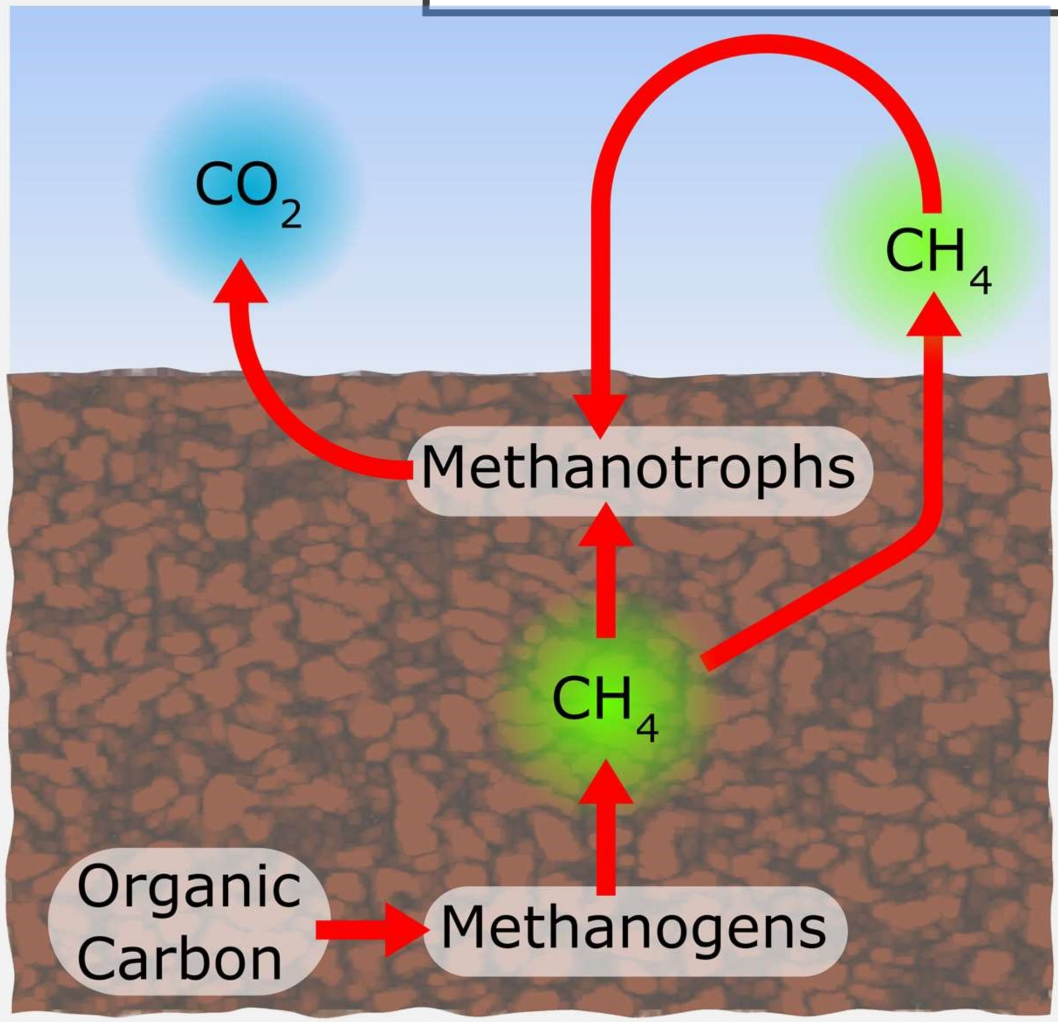
- **Methanotrophs consume significant CH_4 BEFORE reaching atmosphere**
- **NOT considered in global sink estimates**

METHANOTROPHS CONSUME ATMOSPHERIC METHANE



- Atmospheric methane consumption
- Traditional "sink"
- "High-affinity methanotrophs"
- Low methane oxidation rates

METHANOTROPHS ATTENUATE SUBSURFACE METHANE EMISSIONS

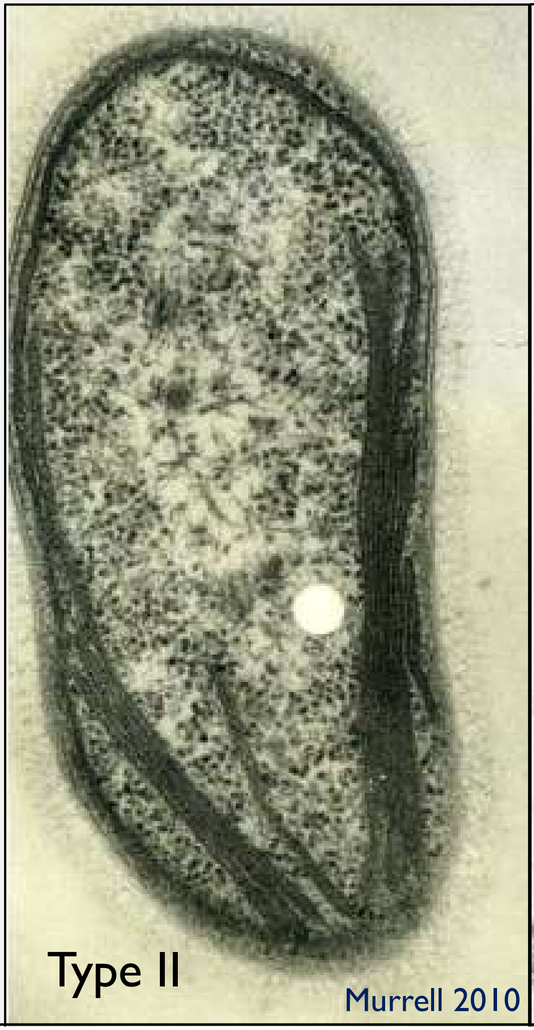


- Methanotrophs oxidize significant methane BEFORE it reaches the atmosphere
- "Low-affinity methanotrophs"
- High methane oxidation rates

METHANOTROPHS ARE FUNCTIONALLY DIVERSE

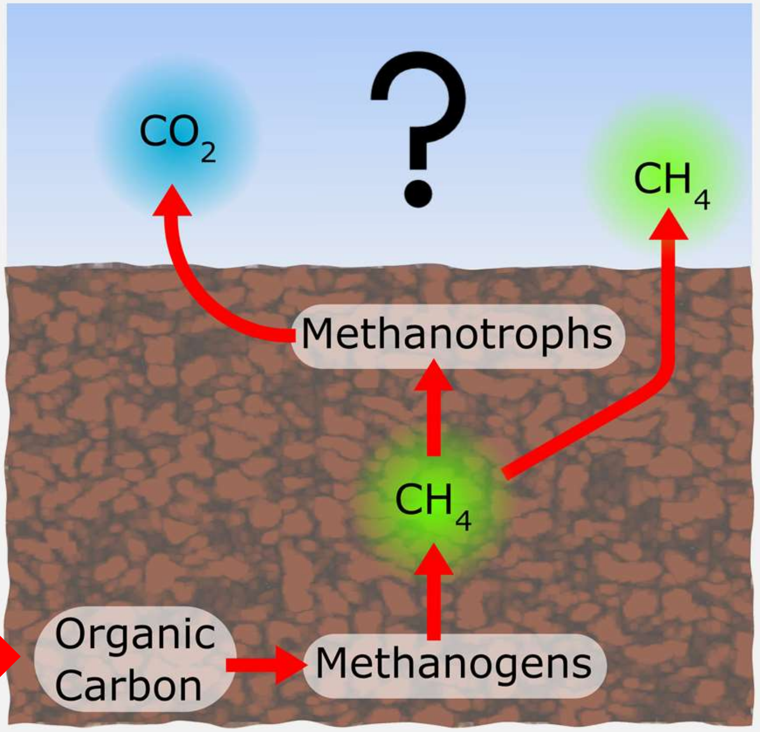
- Affinity for methane
- Response to resource availability
- Alternate substrate utilization
- N-fixation
- Response to stress
- Spore-forming ability

Need to understand COMMUNITY to predict response of methane cycle to perturbations



LEAKING FUEL FROM UST'S PROVIDES SOURCE FOR METHANE GENERATION

- ~569,000 USTs nationwide
- >60% of CA underground storage tanks (USTs) leaking fuel vapors
- Methane dynamics at LUST sites poorly understood



Xerxes Corporation, Minneapolis, MN

GOALS OF RESEARCHING METHANE AT LUST SITES

- Risk management
  - Explosion hazard
  - Increased vapor intrusion risk
- Unique environment
- Laying groundwork for future experiments

- **LUSTs themselves small source globally BUT findings translate to more globally significant methane sources**

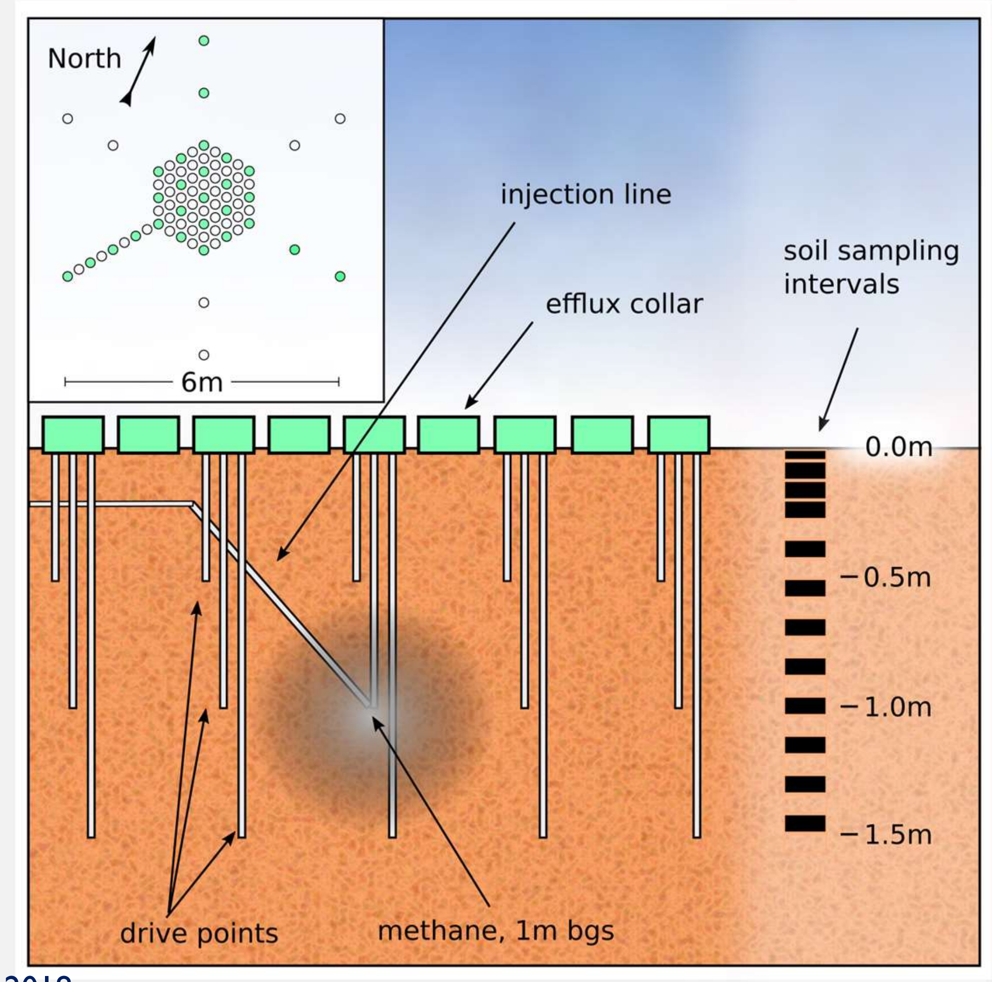
OBJECTIVES

- Characterize methane migration in shallow subsurface
  - Measure lag time for methane oxidation to begin
  - Determine fraction of methane reaching the atmosphere
  - Measure seasonal variability and identify controls on methane migration
- Characterize the relationships among:
  - Abundance of methanotroph groups and community composition
  - Soil moisture
  - Lag period and steady state methane oxidation rates


UC Davis campus
North Fork, Putah Creek
Brooks Road
Brooks Road Parking
Putah Creek
LEHR site
Old Davis Road Parking
Alternative field research sites
Old Davis Road
Legend
Open to Classes and Researchers Only
Open to the Public
Parking
The South bank of Putah Creek is private property - Do Not Trespass
0 1,200 2,400 Feet
N
Putah Creek Riparian Reserve
Main Campus


Credit: Doug Mackay

CONTINUOUS SUBSURFACE METHANE INJECTION



Felice et al., 2018

- Methane injection parameters
  - July 2014 – February 2015 (~7 months)
  - 1000 mL/day varying gas composition
    - 25% CH_4 + 75% N_2 (“Low rate”)
    - 100% CH_4 (“Hi rate”)
  - 1 m below ground surface (BGS)
  - Continuous injection followed by tracer and inhibitor studies

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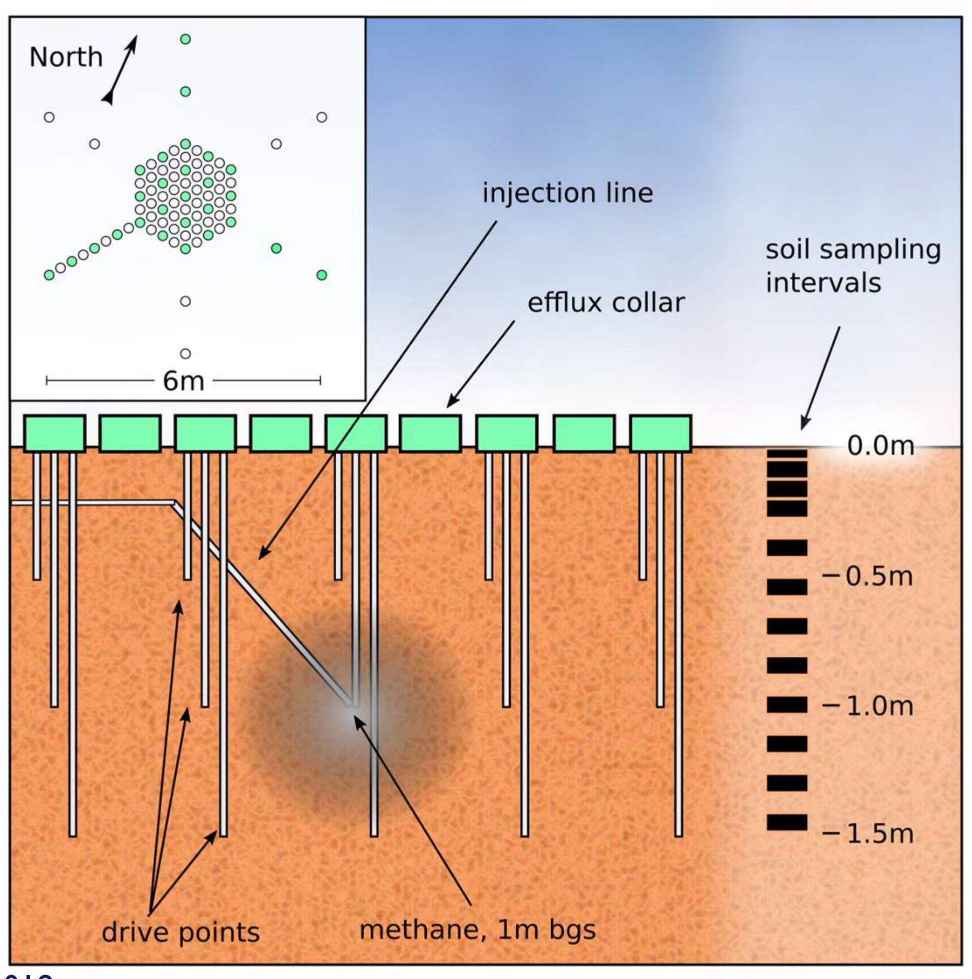


Felice et al., 2018

- Continuous monitoring
  - Soil gas --> CH_4 CO_2, O_2, N_2
  - Efflux --> CH_4, CO_2
  - Soil gas pressure
  - Soil moisture
  - Microbial communities (background and injection point)
    - qPCR
      - Methanotrophs and total bacteria
    - 16S rRNA gene sequencing
- One-time measurements
  - Bulk density
  - Mineral density
  - Organic carbon

Note the vegetation:

Mediterranean climate

=

Seasonal (winter) rainfall

LIGR EFFLUX SYSTEM AND CART

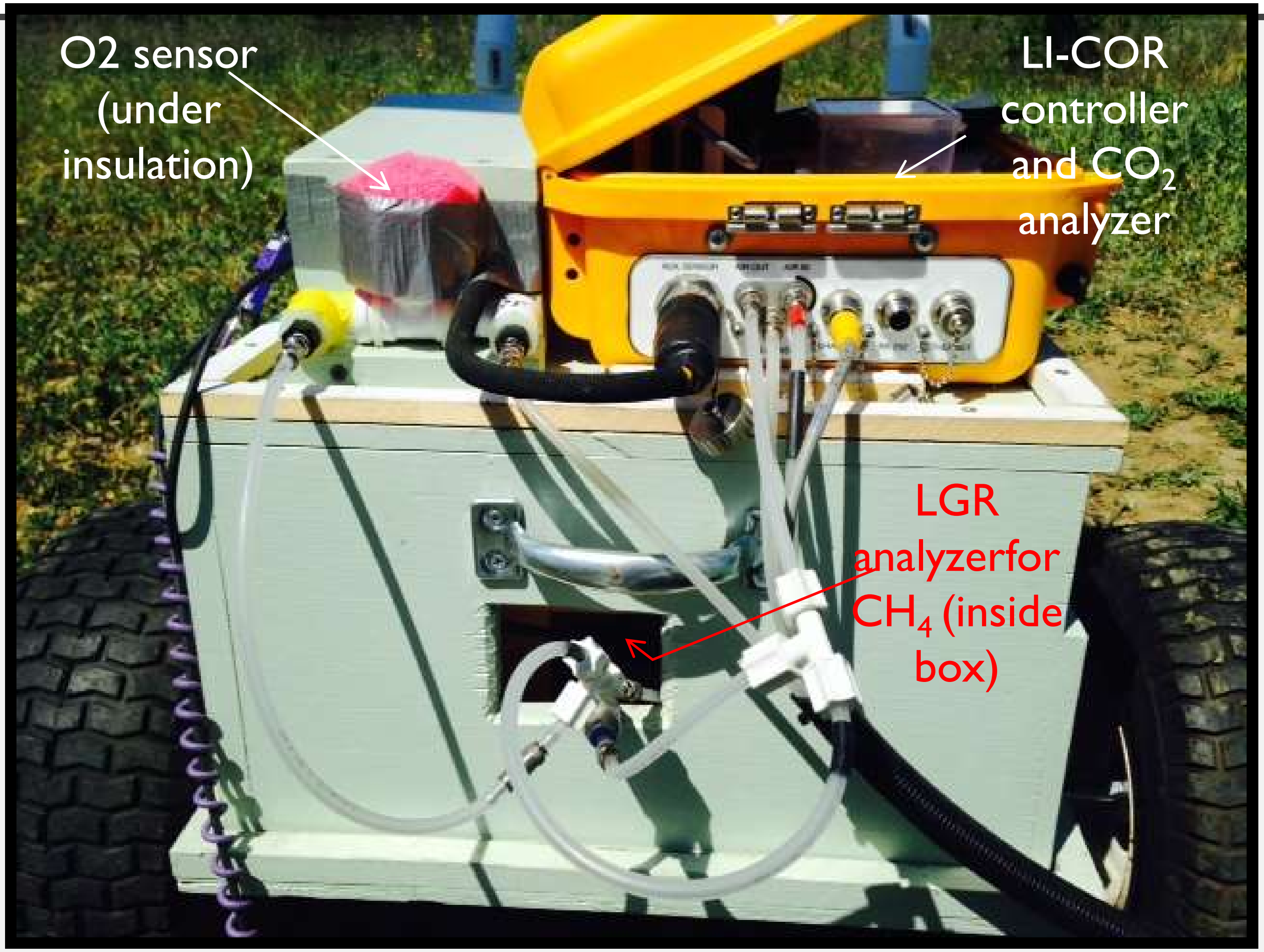


Photo credit: Doug Mackay

MANUAL GAS SAMPLING APPARATUS

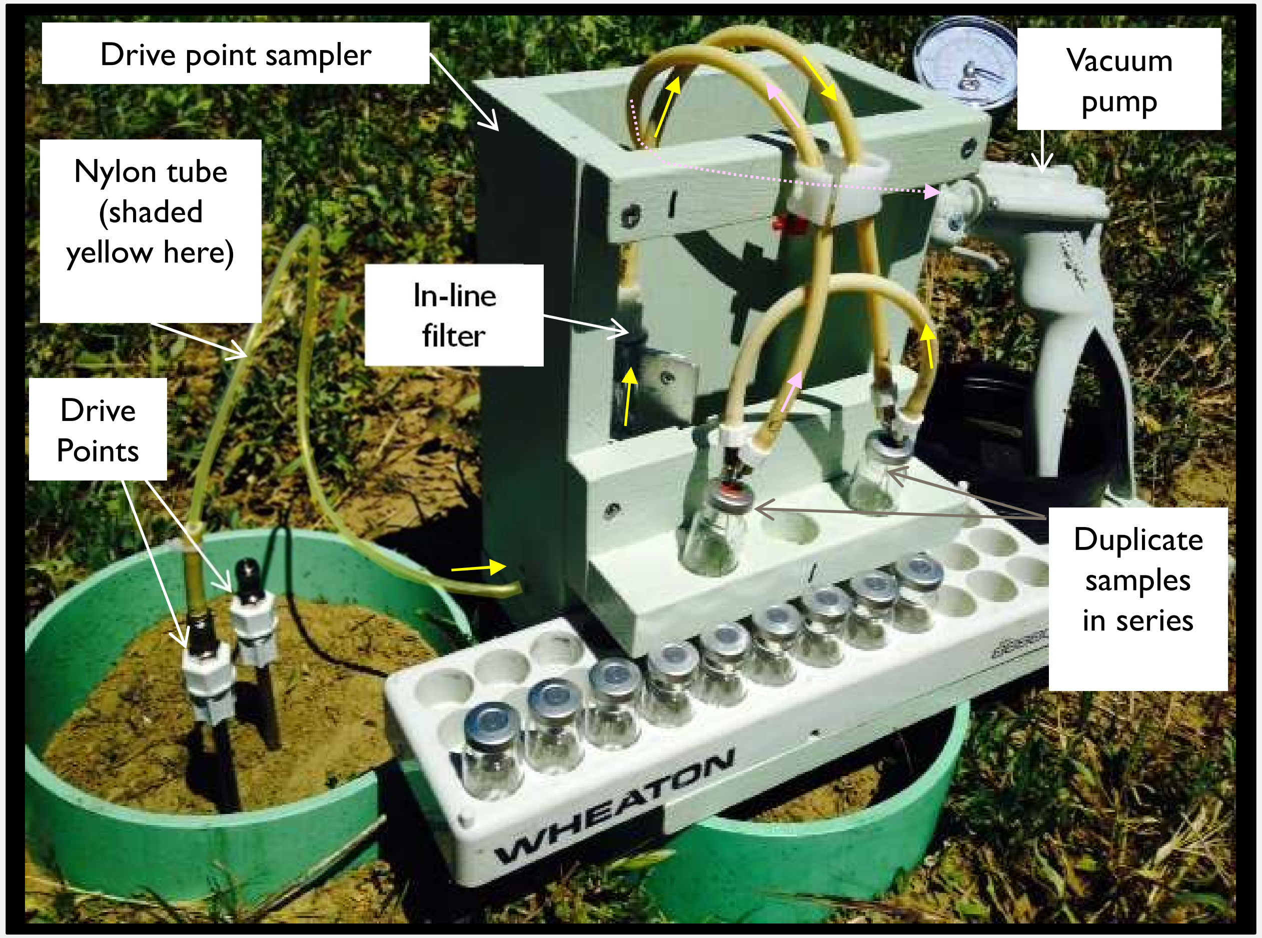


Photo credit: Doug Mackay

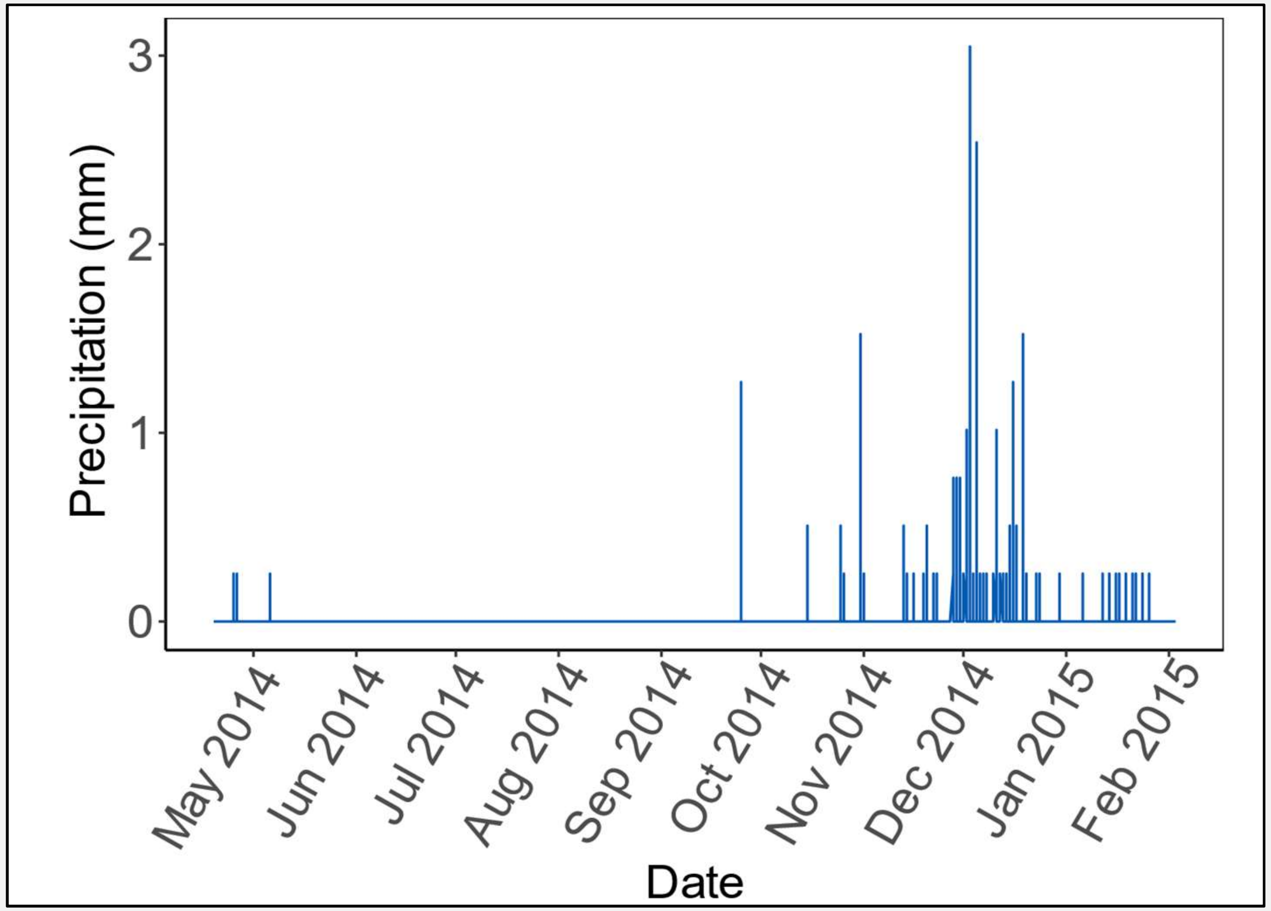
METHANE INJECTION FIELD SITE

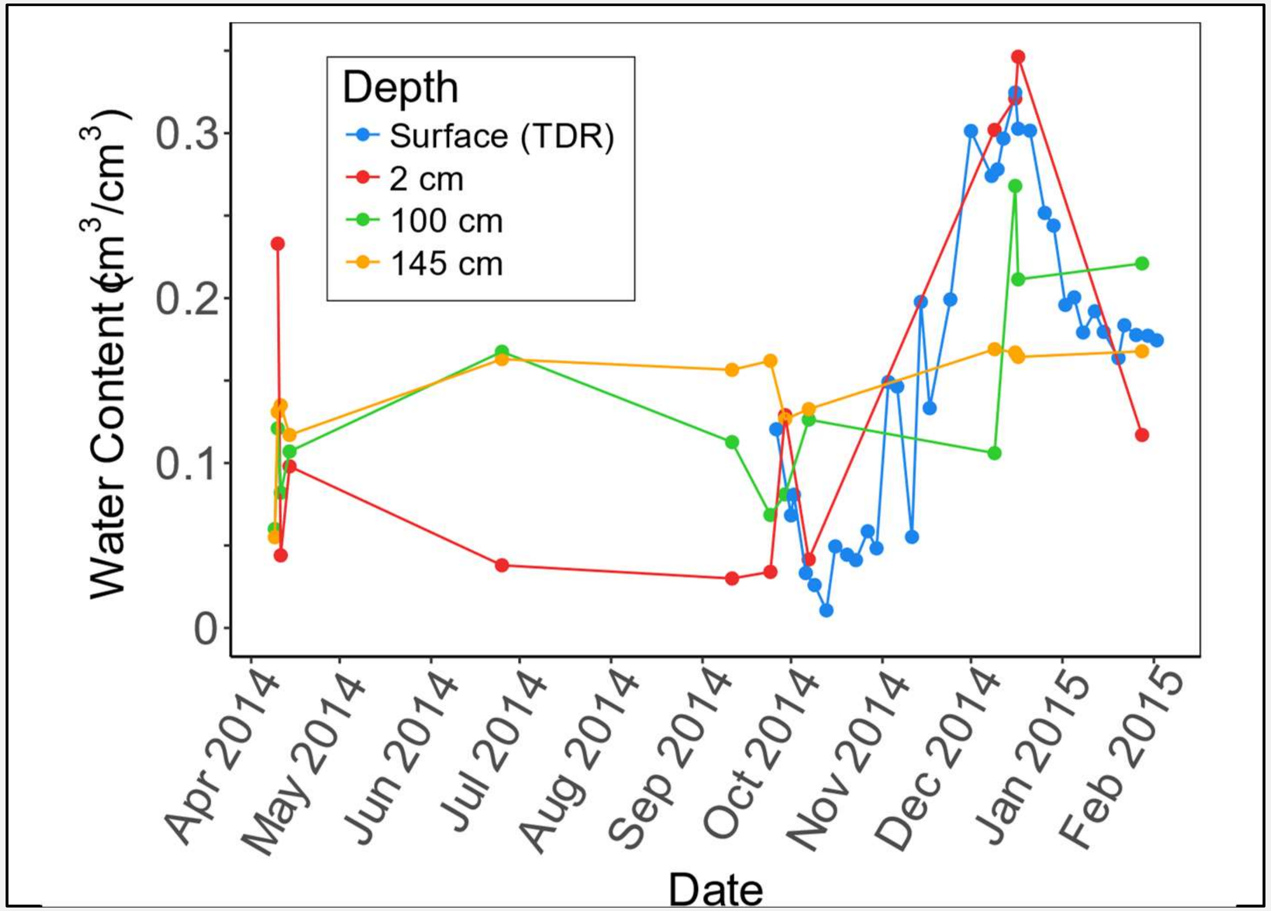
Photo credit: Doug Mackay

HYPOTHESES

- CH_4 oxidation will begin within several days of injection
- CH_4 migration will be tied to soil moisture
- CH_4 inputs will select for competitor methanotroph groups
- Shifts toward competitor methanotroph groups will increase methane oxidation rates
- Methanotroph community composition will be linked to soil moisture

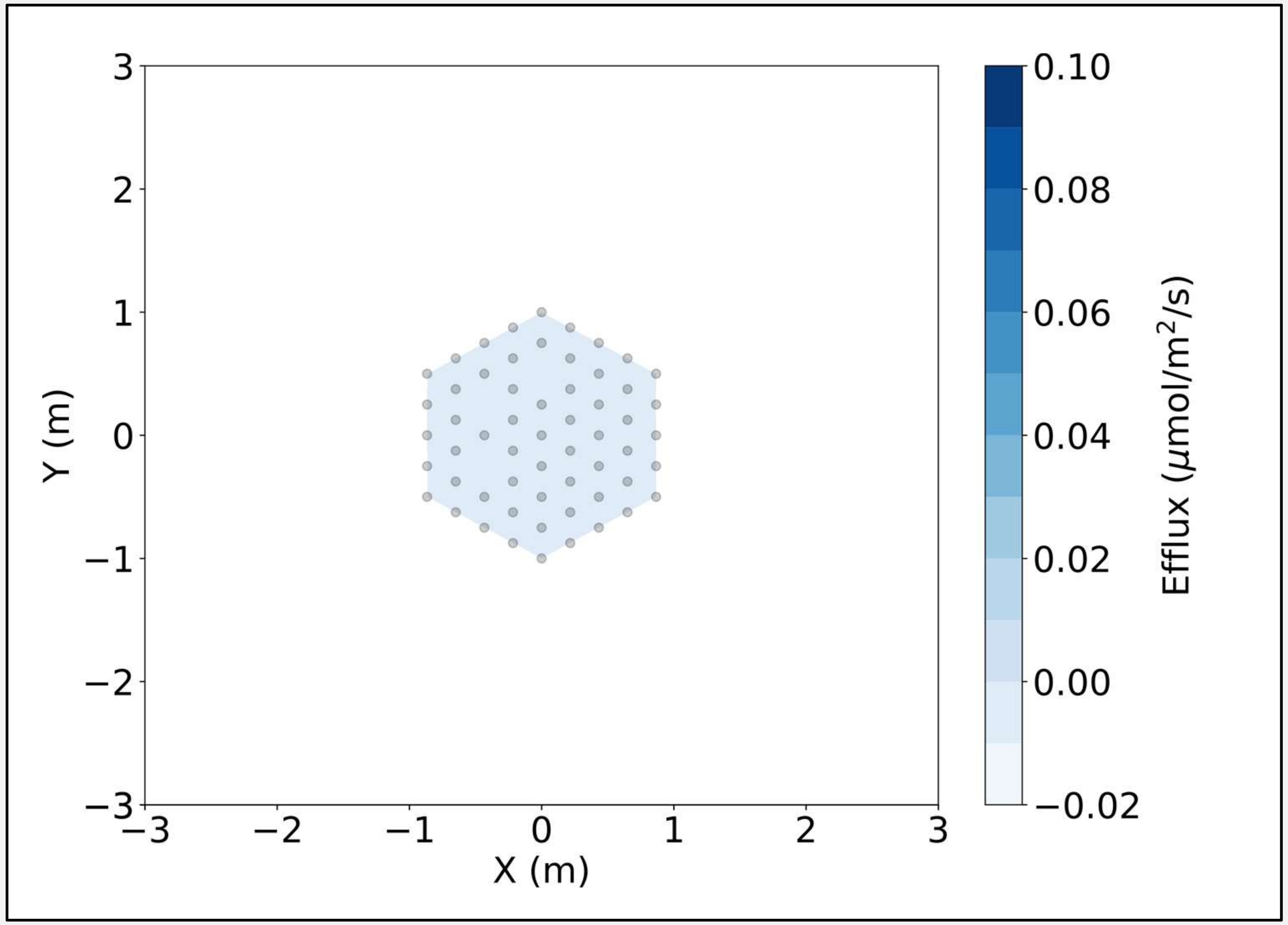
EXPERIMENT SPANNED LONG PERIODS OF DROUGHT



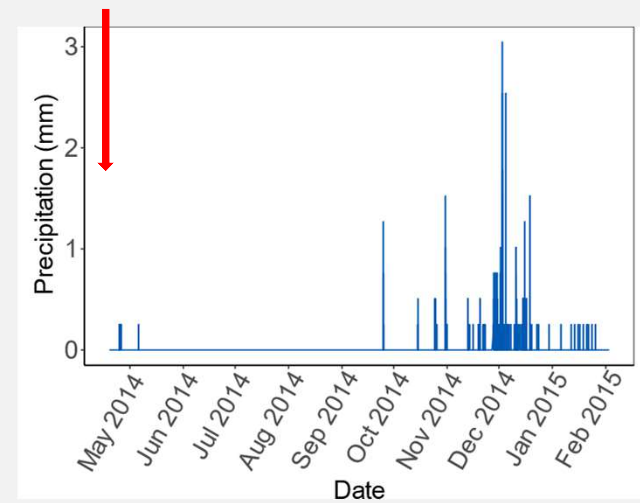


Felice et al. 2018

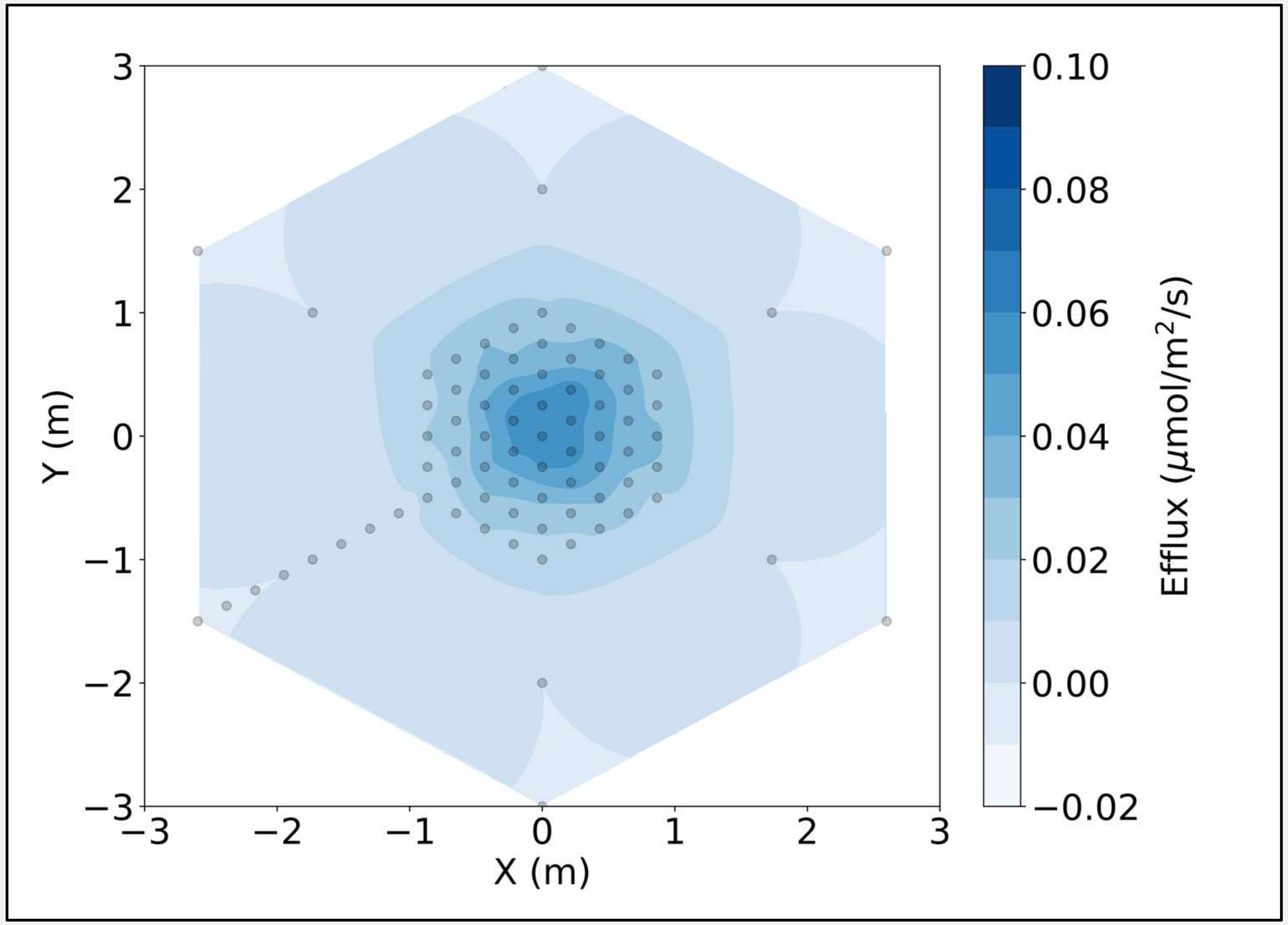
BEFORE INJECTION: SOIL A NET CH_4 CONSUMER



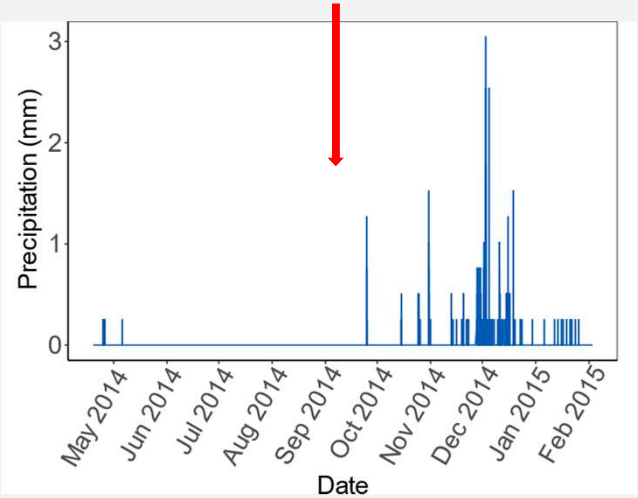
- Before injection:
  - All efflux < 0
  - Net CH_4 consumption



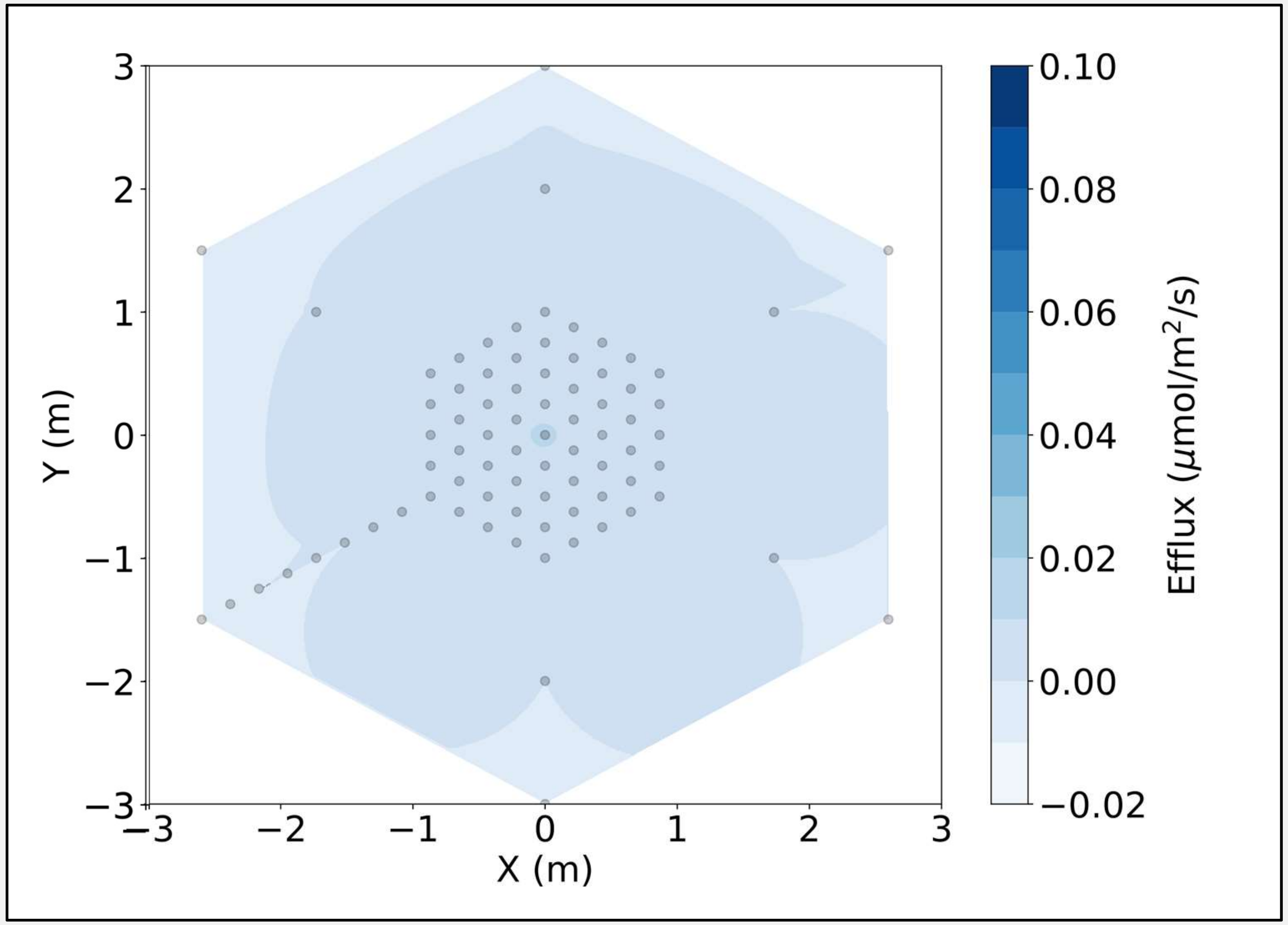
DRY MONTHS FOLLOWING INJECTION: SOIL A LARGE NET CH_4 EMITTER



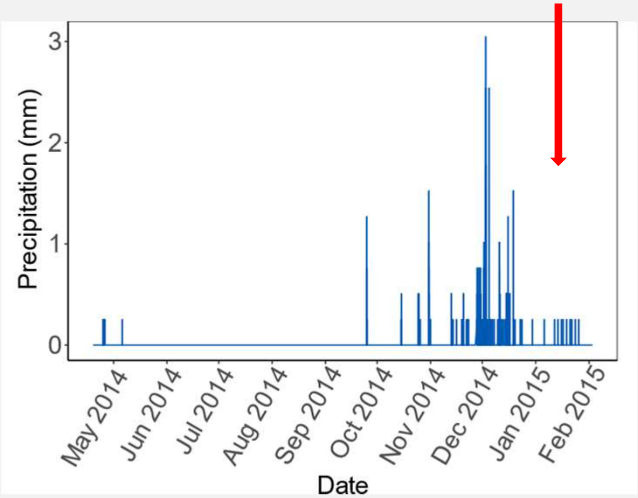
- During dry months:
  - CH_4 efflux high (34-52%)
  - CH_4 oxidation low



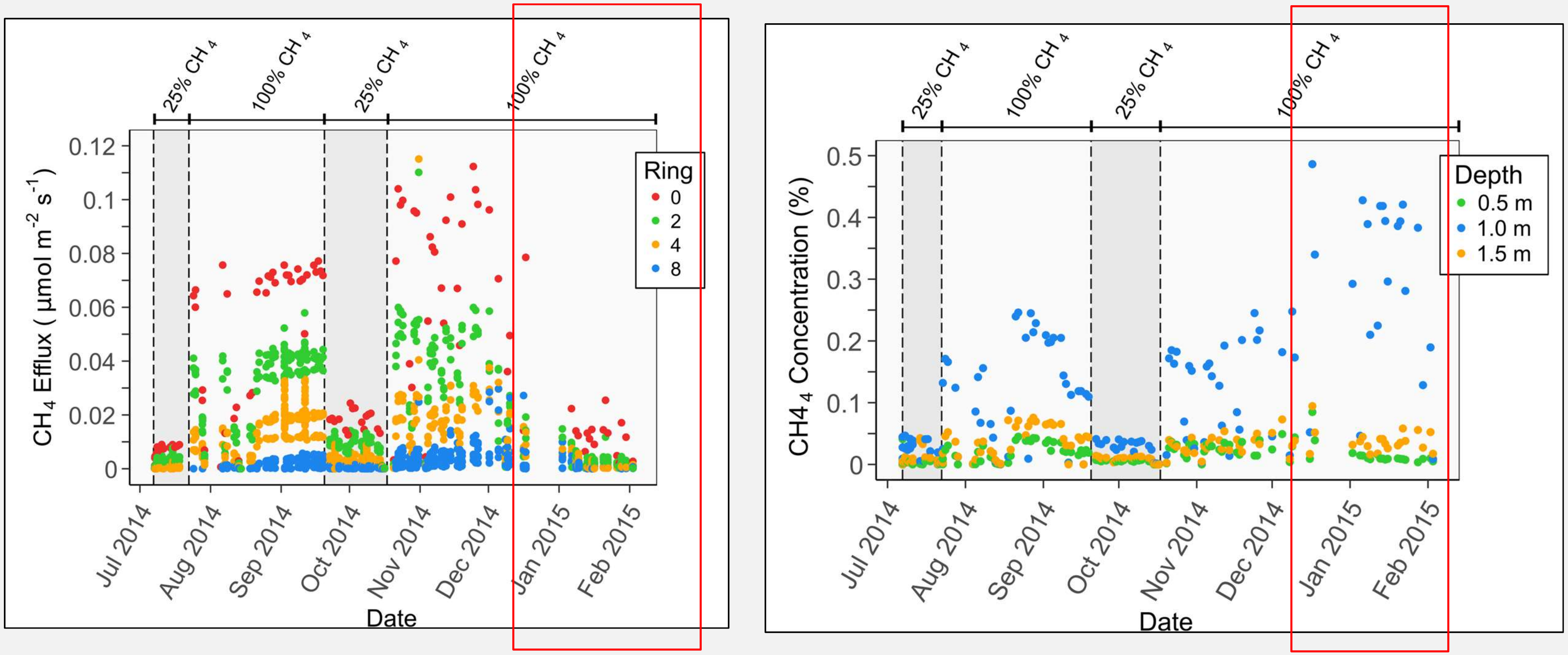
WET MONTHS FOLLOWING INJECTION: SOIL A SMALL NET CH_4 EMITTER



- Following increased moisture:
  - CH_4 efflux low (<2%)
  - CH_4 oxidation high



TRENDS IN EFFLUX AND SOIL GAS DIVERGE IN FINAL MONTH



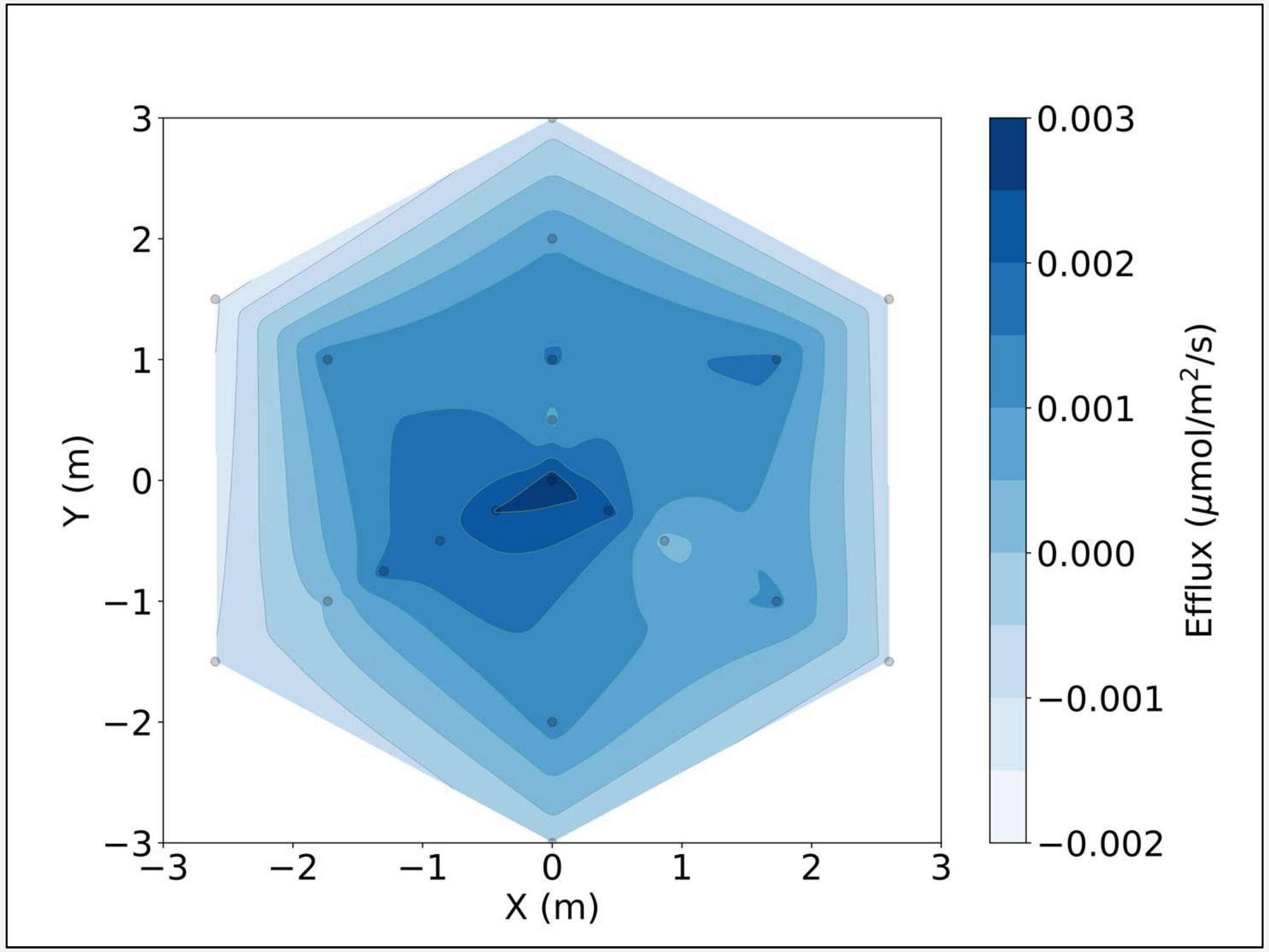
Felice et al. 2018

DECREASED POROSITY ALONE CANNOT ACCOUNT FOR DECREASED EFFLUX

- 3.4x efflux decrease expected from diffusion limitation

vs

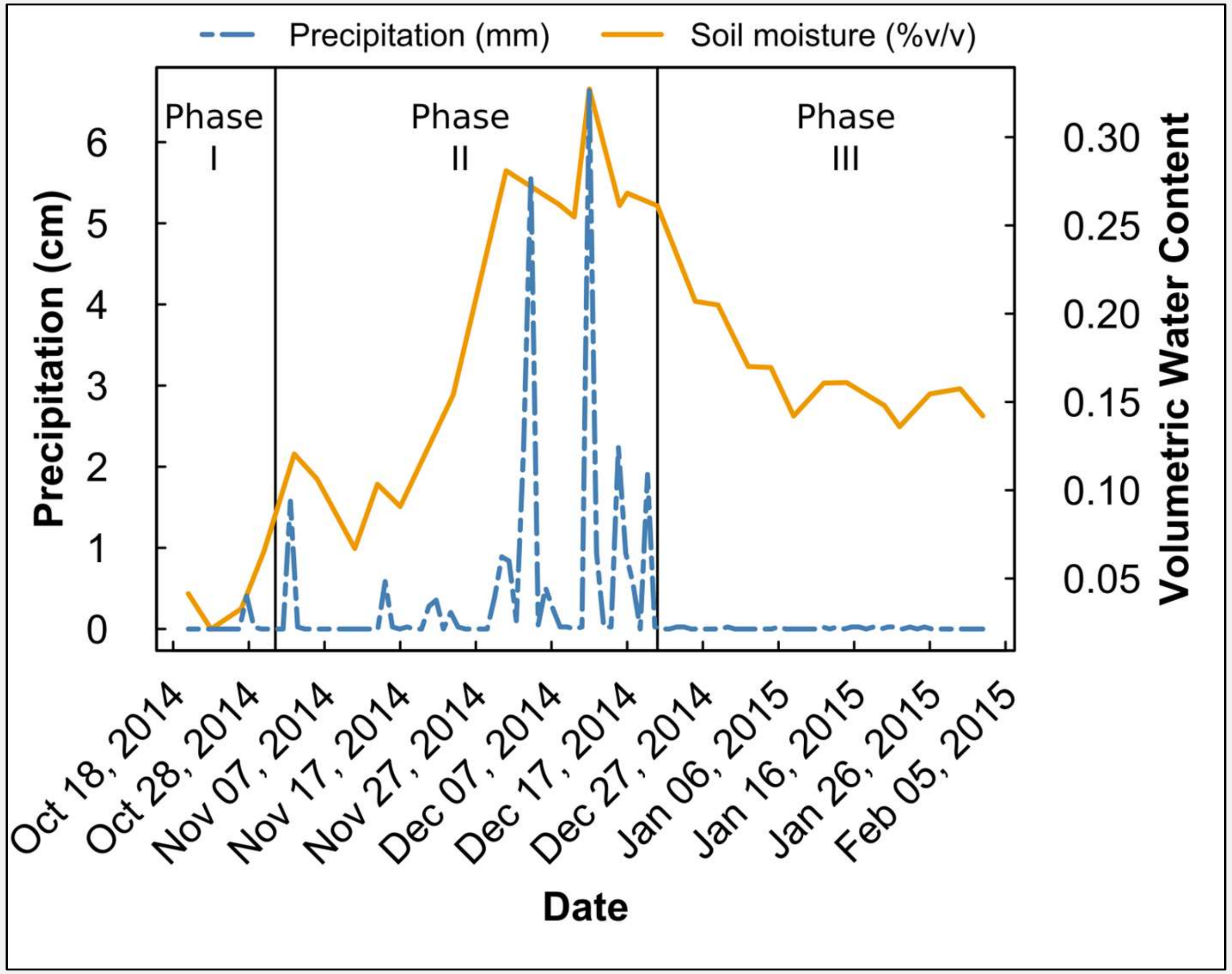
- 25x efflux decrease observed



CONCLUSIONS – TRANSPORT

- CH_4 migration was rapid – several days to steady state efflux
- Soil moisture was a primary control on methane migration
  - Physical: decreased air-filled pore space
  - Biological: relief of physiological moisture stress on methanotrophs

METHANOTROPH DATA FOCUSED ON FINAL INJECTION PERIOD

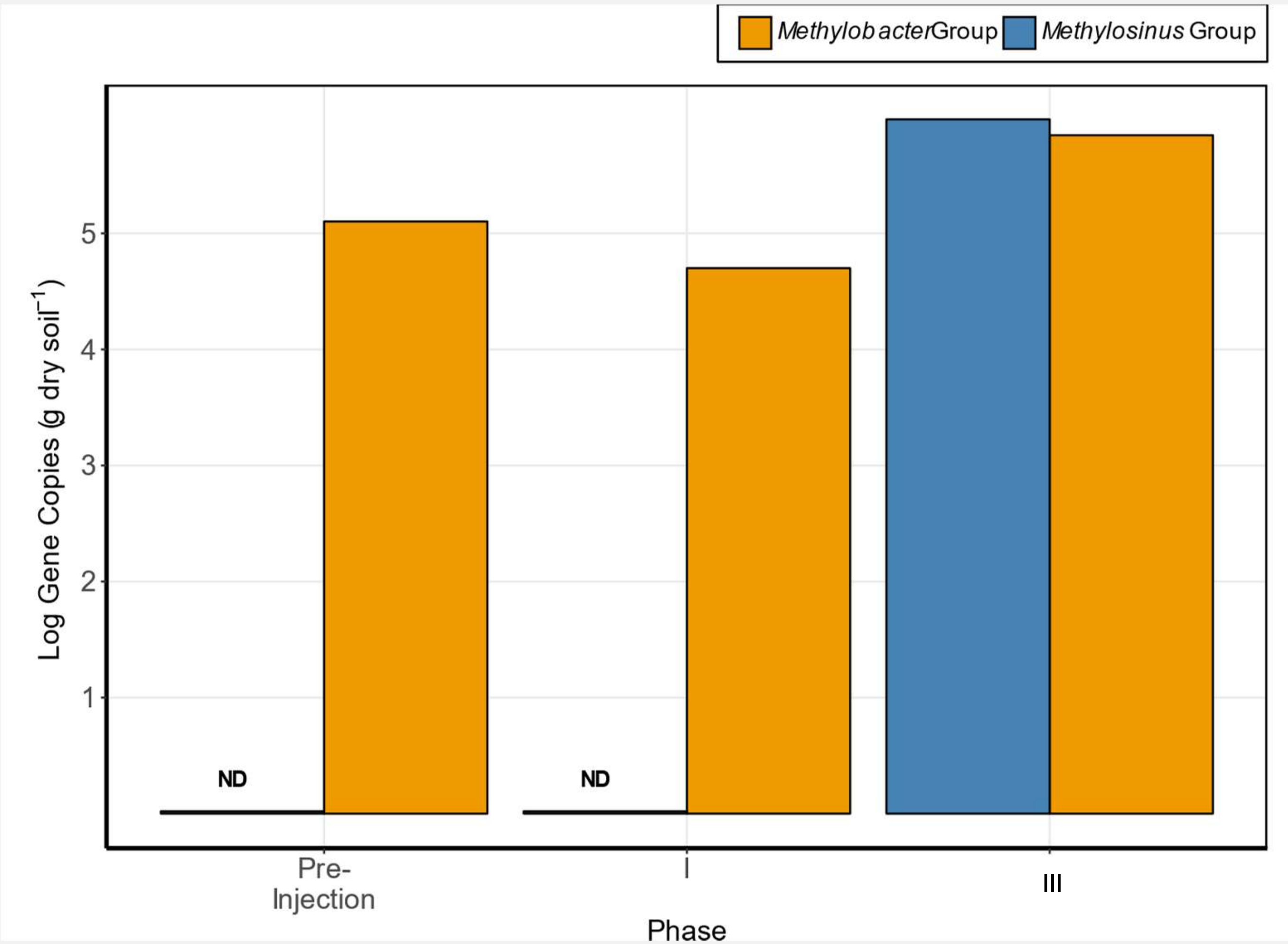


- 3 distinct phases
  - I: Very low soil moisture, no precipitation
  - II: High precipitation, increasing soil moisture
  - III: Low precipitation, decreasing soil moisture

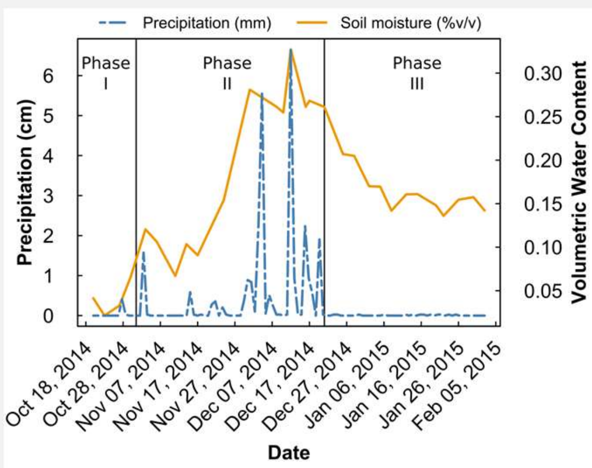
Felice et al. 2018

Felice et al. 2018

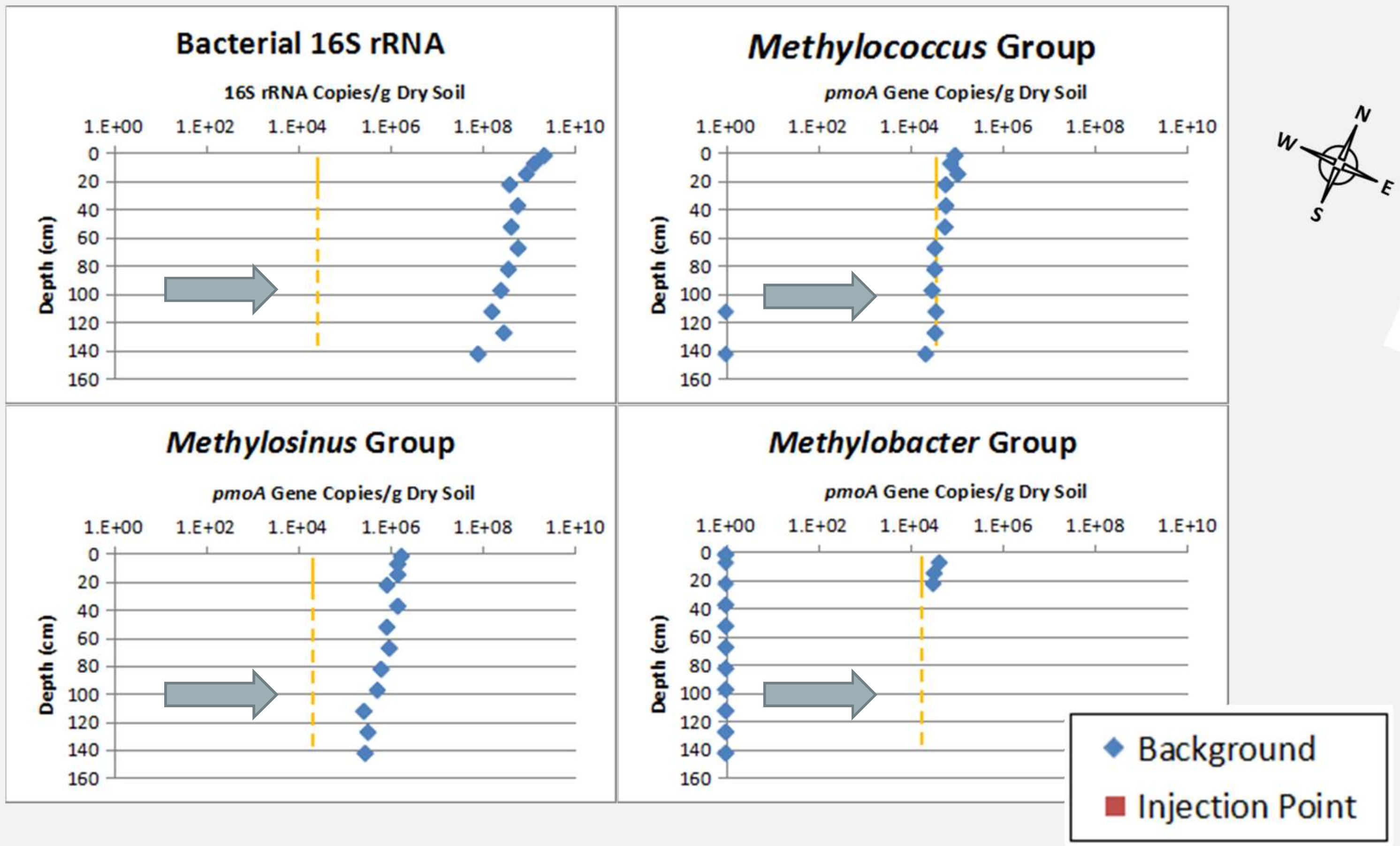
METHYLOBACTER/METHYLOSARCINA RESPONDS TO INCREASED SOIL MOISTURE

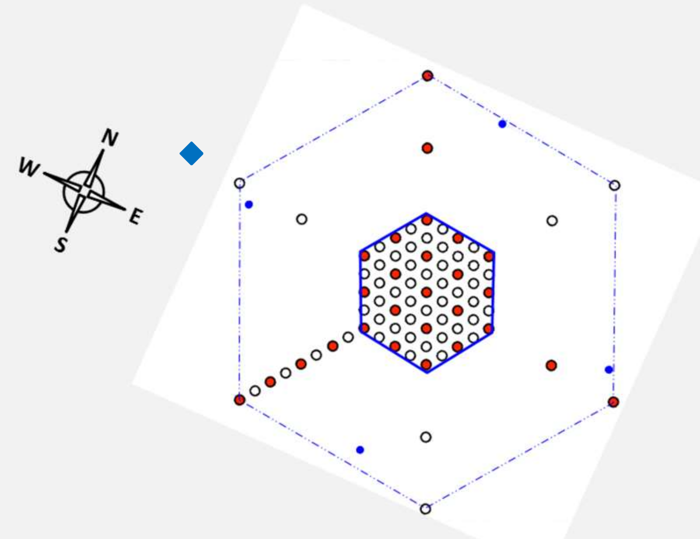


- Response observed:
  - ~1 month after precipitation
  - ~6-7 months of methane injection



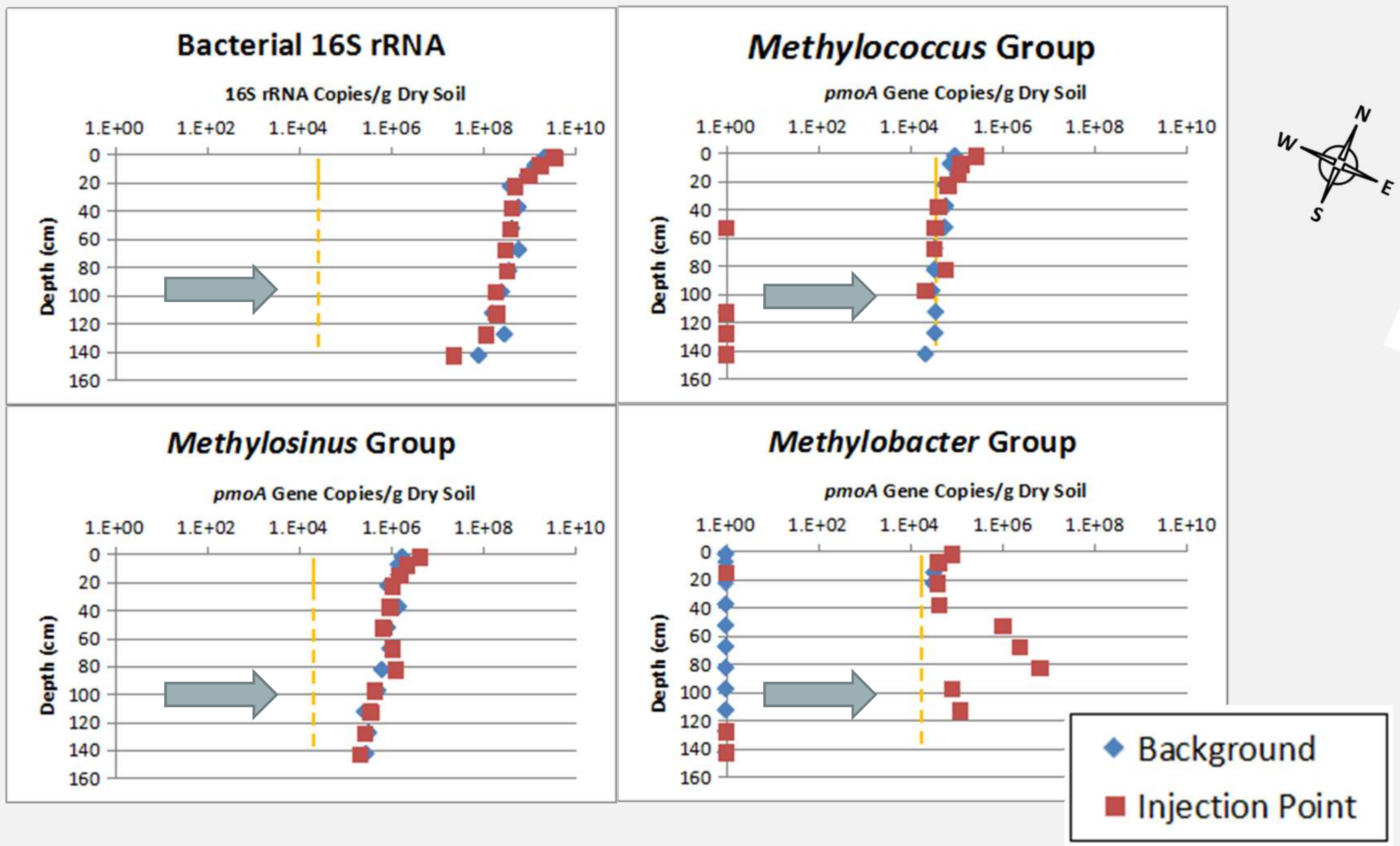
METHYLOBACTER/METHYLOSARCINA LOCALIZED NEAR INJECTION POINT

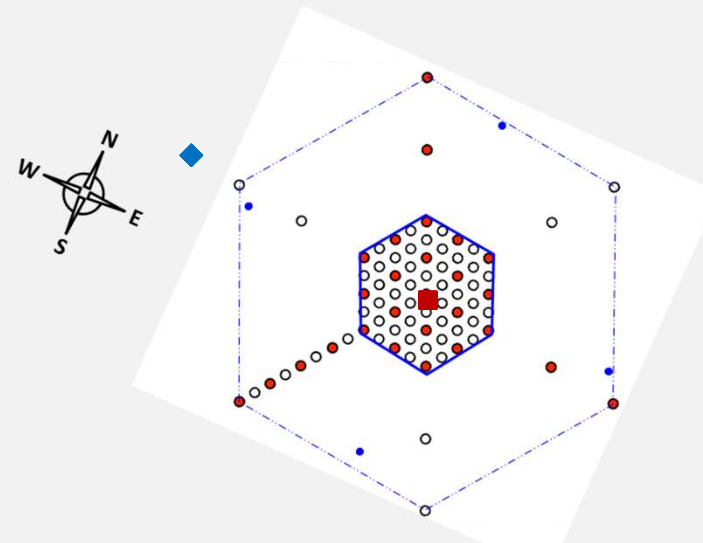




•*Methylosinus* group dominates under natural conditions (atmospheric methane scavengers?)

METHYLOBACTER/METHYLOSARCINA LOCALIZED NEAR INJECTION POINT





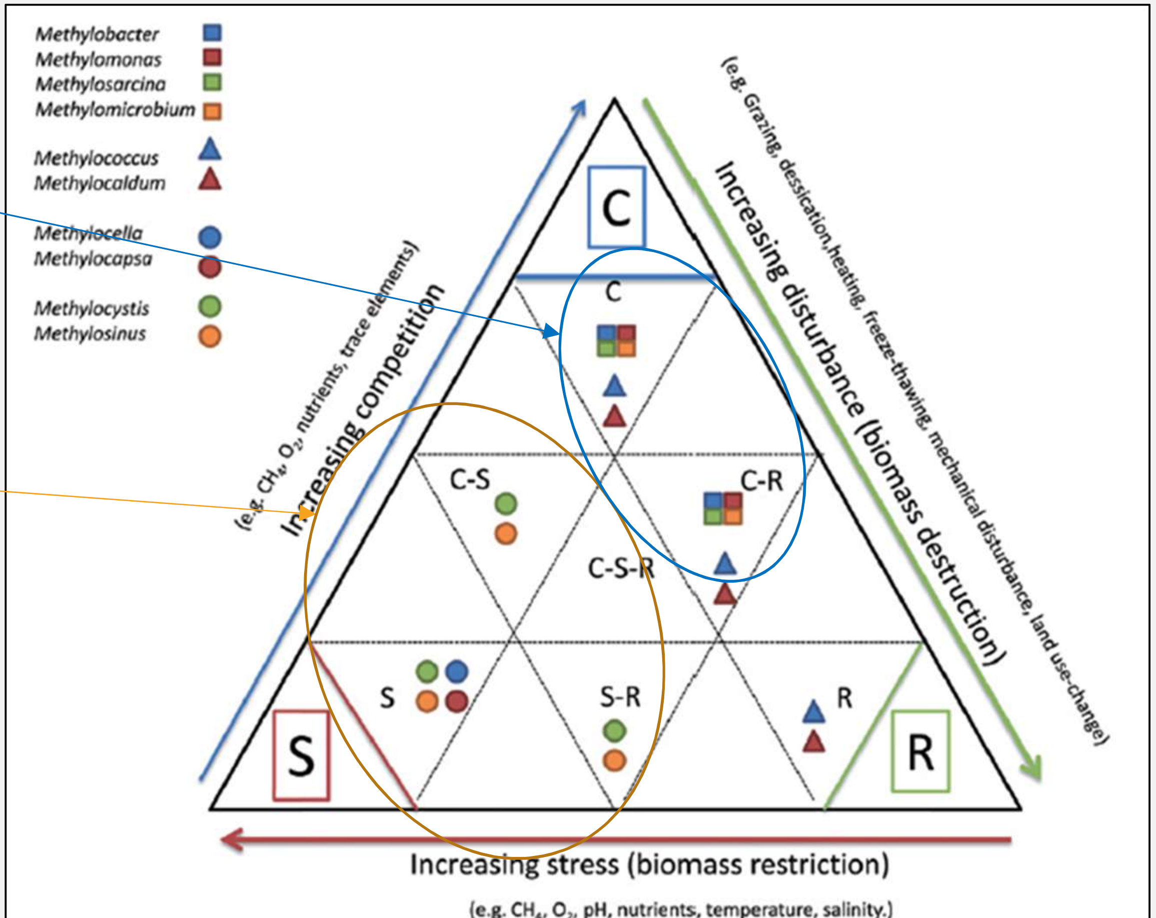
•*Methylosinus* group dominates under natural conditions (atmospheric methane scavengers?)

•*Methylobacter* group dominates in region immediately above experimental release, as expected (adaptable to higher methane concentrations)

OBSERVATIONS FIT ECOLOGICAL MODELS FOR PLANTS

- *Methylobacter* group responds to high resource availability
  - Only under favorable conditions

- *Methylosinus* group persists under drought conditions



Ho et al. 2013

CONCLUSIONS – MICROBES

- Methanotroph groups and their ecological niches influence the fate of subsurface methane
- Experiment supports the application of the CSR triangle to methanotrophs

ADDITIONAL STUDIES

- Numerical modelling studies to further elucidate controls on methane migration
- Studies involving gasoline or biofuels injection
  - Determine methane generation rates
  - Identify impacts of fuel constituents on methanotrophs
- Controlled studies to examine interactions between methanotrophs and non-methanotrophic microbes

ACKNOWLEDGEMENTS

- Advisers
  - Kate Scow
  - Doug Mackay
- Dissertation Committee
  - Kate, Doug, and Jorge Rodrigues
- Scow and Mackay Groups
  - Nick DeSieyes
  - Sherry Peng
  - Radomir Schmidt
  - Leah Zivalic
  - Melissa Bolotaolo
  - Maya Buelow
  - Jason Emmons
  - Mirann Tsumura
  - Nicole Spadone
  - Evan Dumas
  - Jason Brooks
- Approvals and other support
  - Sue Fields
  - Andrew Fulks
  - Brian Newman
  - Gary Lemon
  - Josuwa Bernardo
  - Anthony Endow
- The Rodrigues Lab
- SBG students and faculty
- Funding
  - American Petroleum Institute
  - Chevron Technology Ventures
  - USDA NRCS
  - USDA National Institute of Food and Agriculture
  - Superfund Research Program
  - Henry A. Jastro Award
  - Soils and Biogeochemistry Fellowship

FIGURE/PHOTO REFERENCES

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