Prairie NSZD: A comparison of NSZD rates across ~~eight~~ nine sites using new high-data density technology.

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Environmental Material Science Inc.

Saskatoon, SK

remediation technologies symposium EAST

Niagara Falls | 2022

1 June 2022

Your roadmap for today

Site-specific stoichiometry

Pedotransfer and soil moisture

Continuous measurements
High data density

Soil Sense

NSZD Overview

Natural Source Zone Depletion Explained

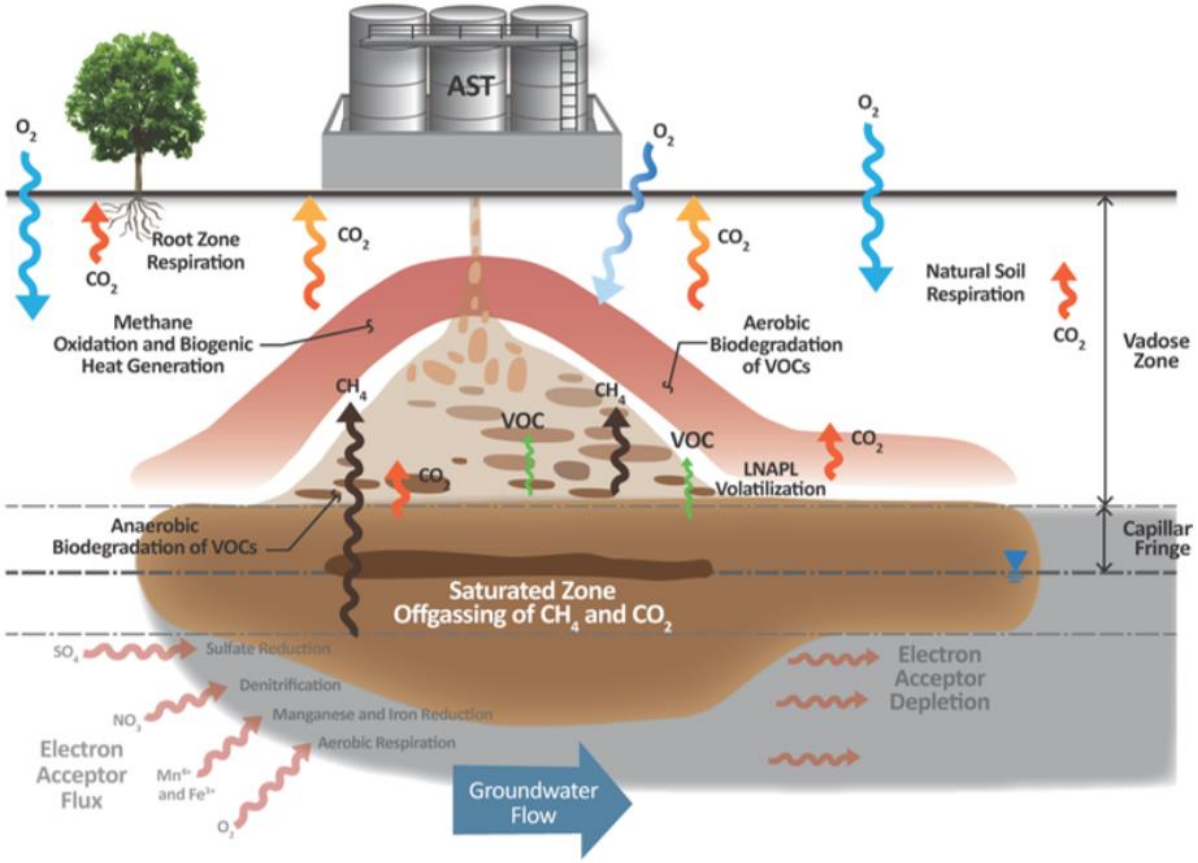


Figure 7: Conceptualisation of LNAPL NSZD processes (from API 2017)

Aerobic Transport

Methane Oxidation

$$CH_4 + 2O_2 \rightarrow CO_{2\,(g)} + 2H_2O$$

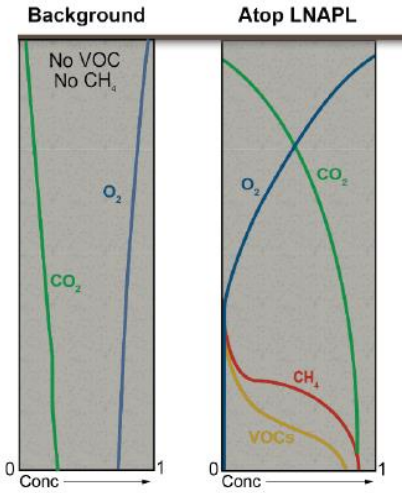
Methane Generation

$$C_8H_{18} + 3.5\ H_2O \rightarrow 1.75\ CH_{4\,(g)} + 6.25\ CO_{2\,(g)}$$

CRC CARE Technical Report no. 46

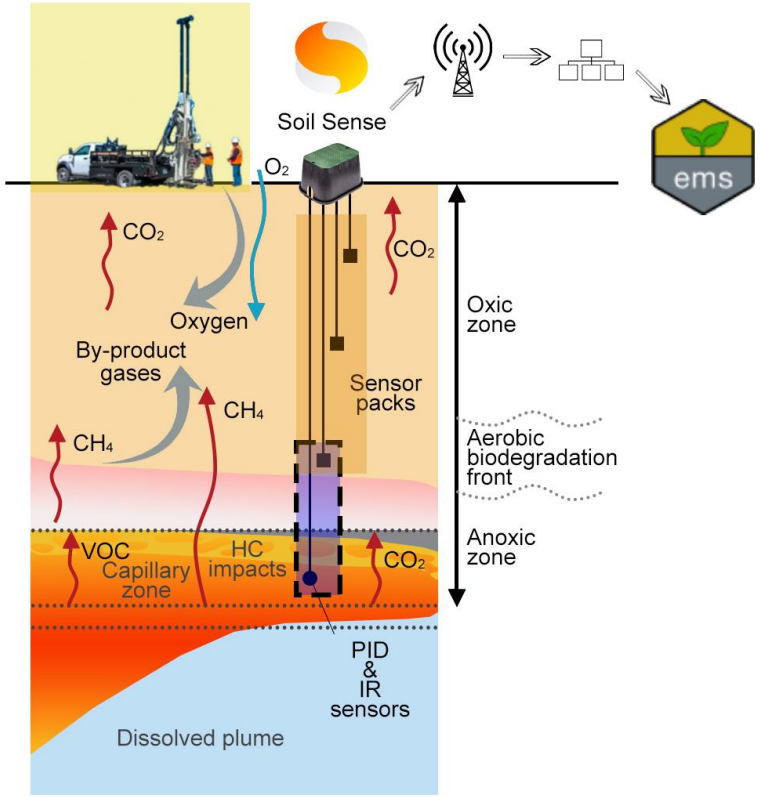
The role of natural source zone depletion in the management of light non-aqueous phase liquid (LNAPL) contaminated sites

Concentration Gradient Method



Site-Specific

Empirical stoichiometric conversion: benzene–CO_2



Persistent Measurements

Hydrocarbons (source) and CO_2 efflux (products)

Fick's First Law of Diffusion - rate of diffusion is proportional to the concentration and surface area

CRC Care 2018

1. $J = D_v^{eff}(\frac{dC}{dZ})$

J = steady state diffusive flux (g/m^2-soil/s)
D_v^{eff} = effective vapour diffusion coefficient (m^2/s)
$\frac{dC}{dZ}$ = soil gas concentration gradient (g/m^3-m)

2. $J_{impacted} - J_{background} = J_{corrected}$

3. Theoretical stoichiometric conversion: benzene–CO_2

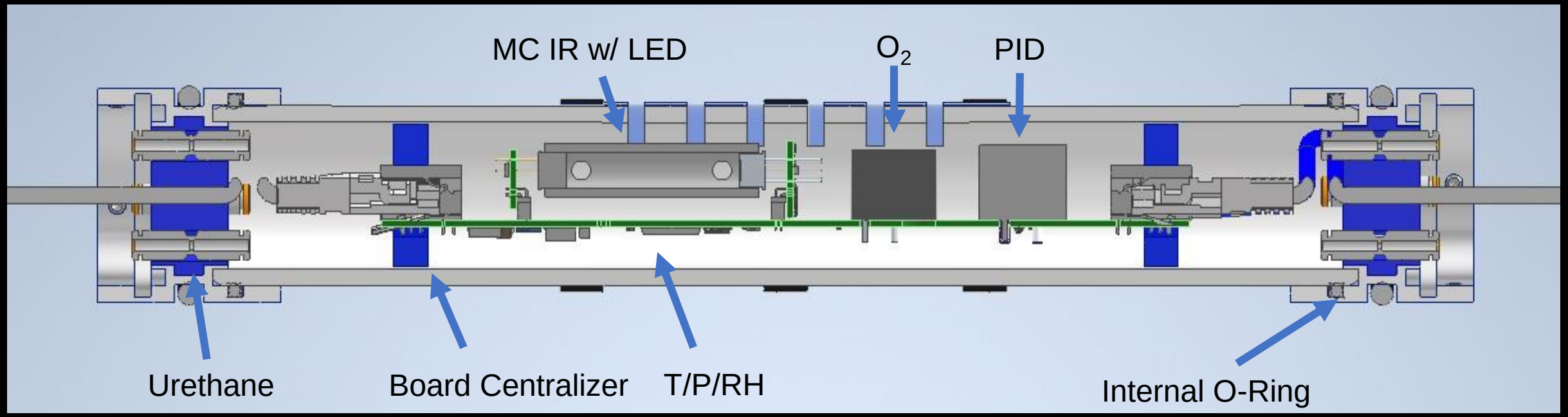
$2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O$
$2C_6H_6$: 2*(12.011 g/mol*6 + 1.008 g/mol*6) = 156.223 g/mol
$12CO_2$: 12*(12.011 g/mol + 15.999 g/mol*2) = 528.096 g/mol

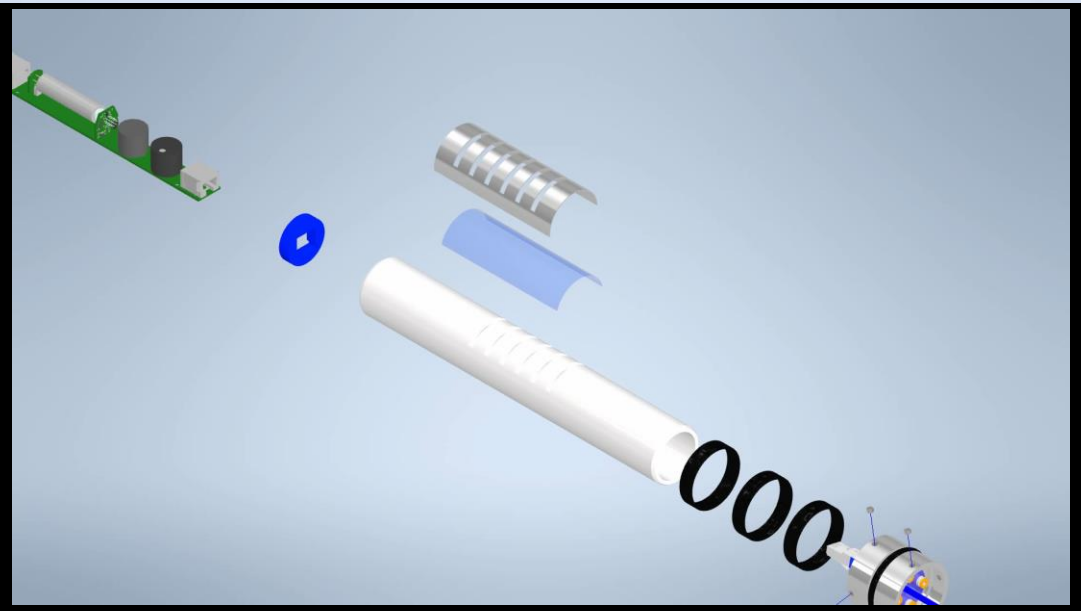
When 156 g of C_6H_6 are consumed, 528 g CO_2 are produced
$Stoich_{CO_2}$ = 156 / 528

4. Natural Source Zone Depletion

NSZD = $J_{corrected}$*$Stoich_{CO_2}$

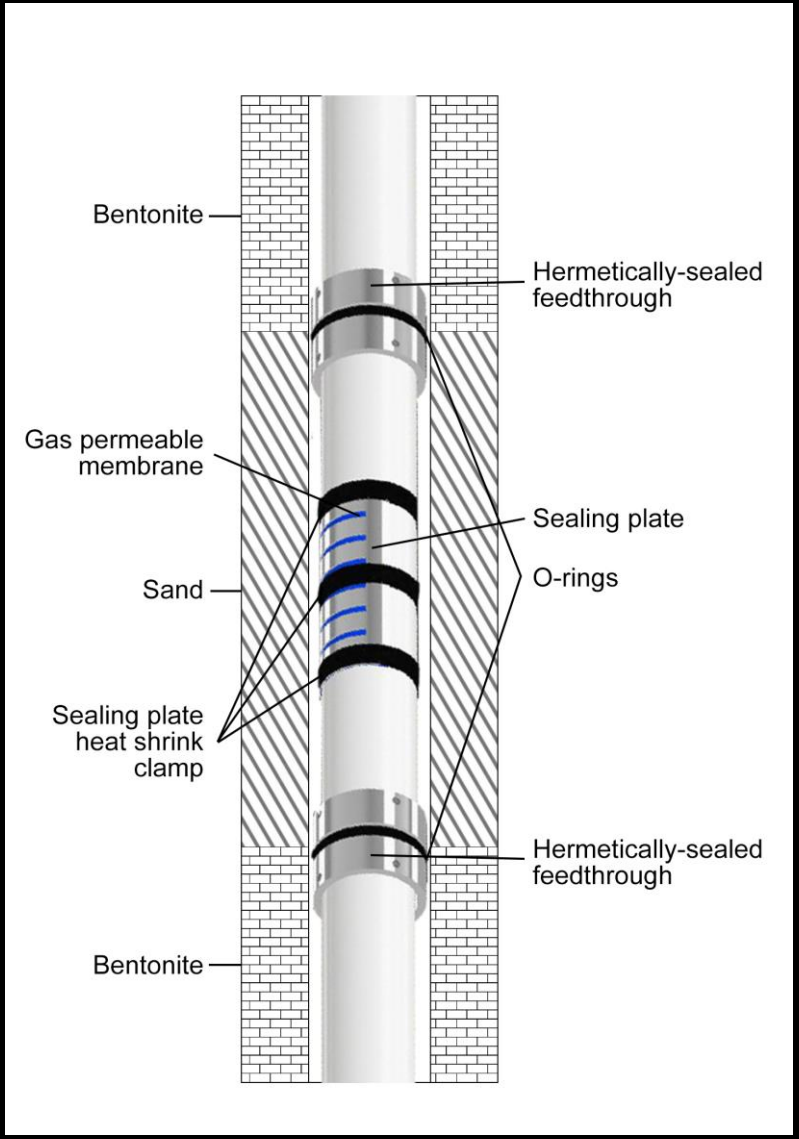
Soil Sense


MC IR w/ LED
O_2
PID
Urethane
Board Centralizer
T/P/RH
Internal O-Ring

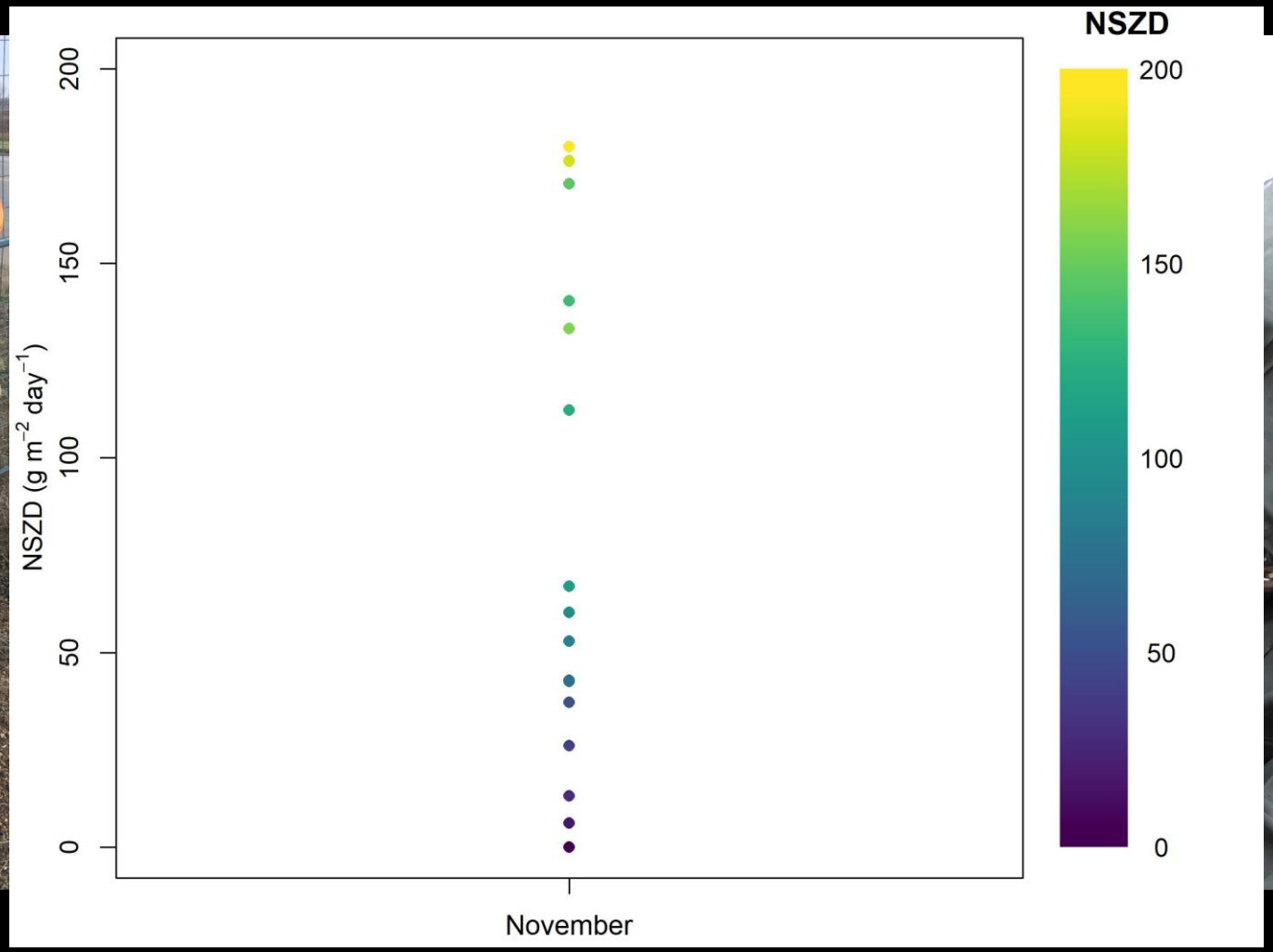


Soil Sense

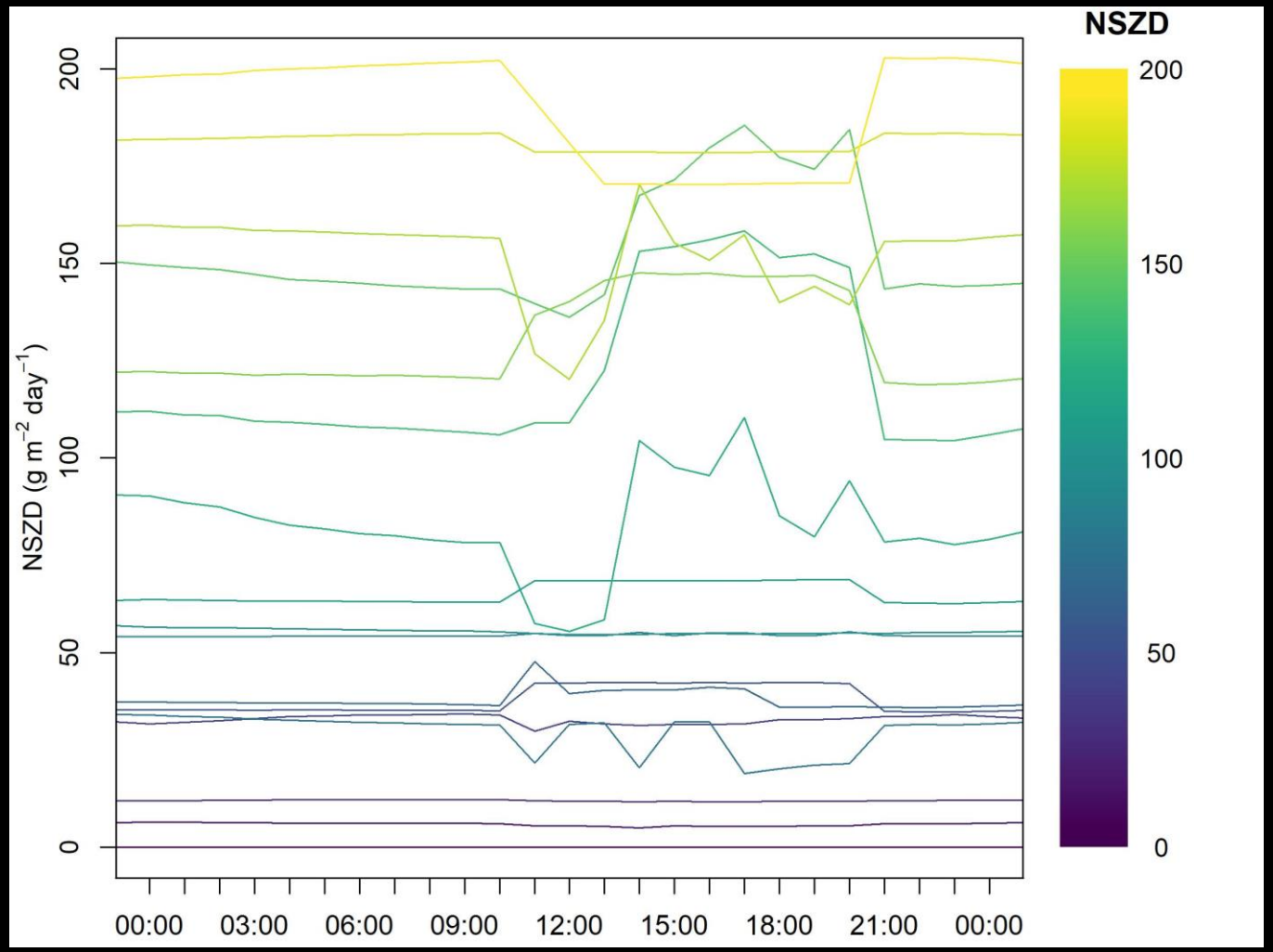
- **Fits into normal groundwater casings**
  - Groundwater sampling tube for normal low flow sampling.
- **Permeability estimates for each installation.**
- **Multi-channel IR with LED Source**
  - Lower Power Consumption
  - Battery Powered and/or Solar Powered
- **LoRa Top Communication Module**
  - Collects data and transmits to online database
  - Dashboard design to fit user needs.



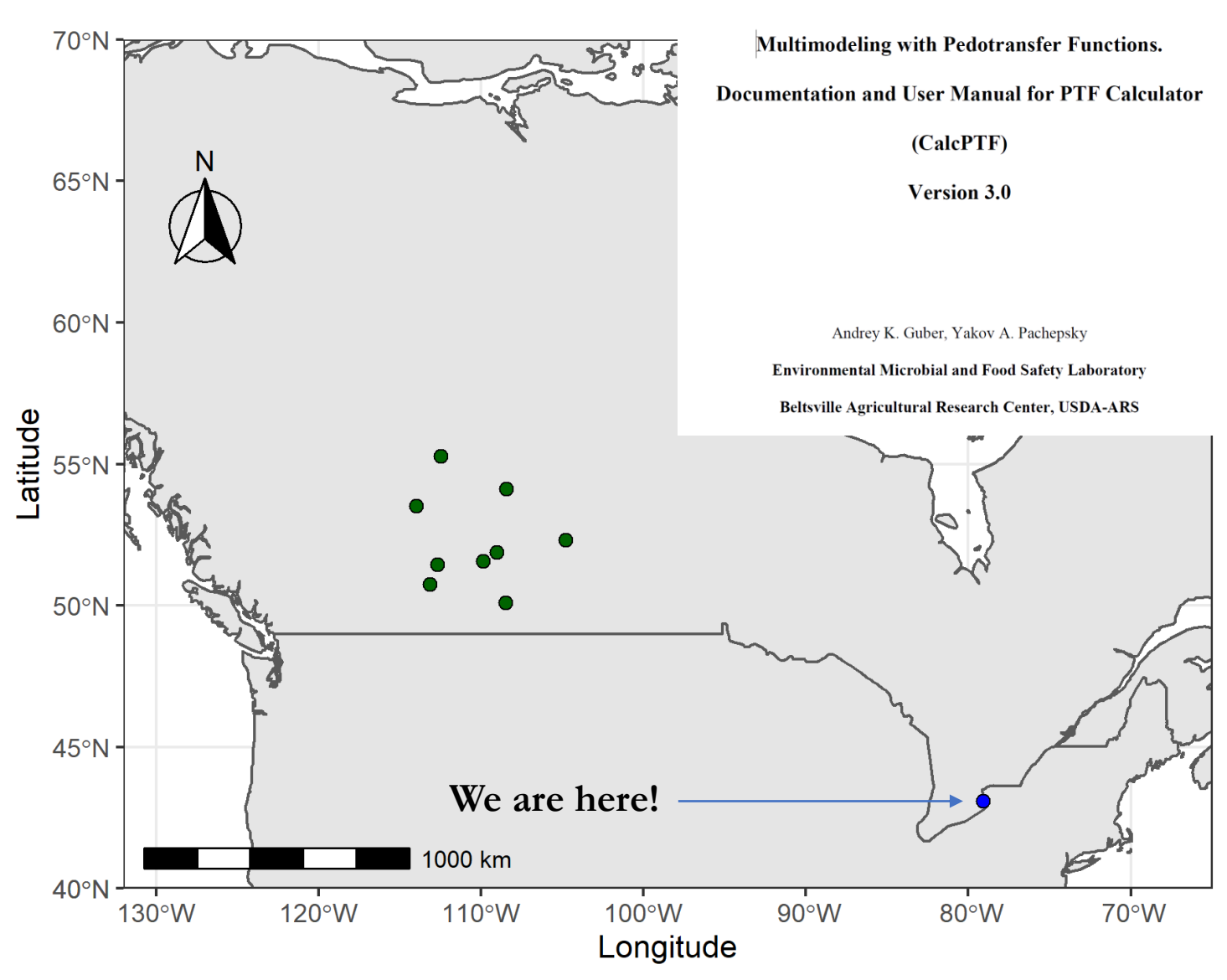
Low sampling frequency (point-in-time is the "pits")

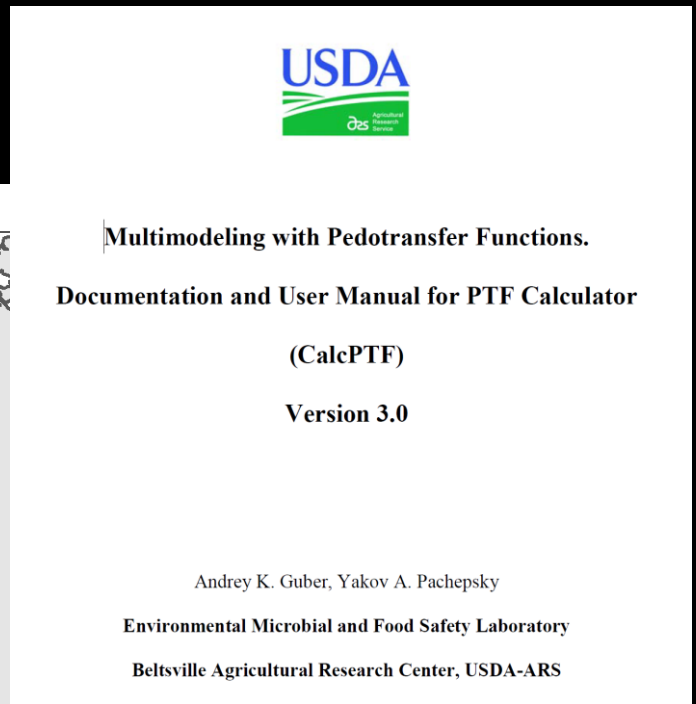


Soil Sense collects 48 measurements per day



The Sites





USDA

Multimodeling with Pedotransfer Functions.

Documentation and User Manual for PTF Calculator

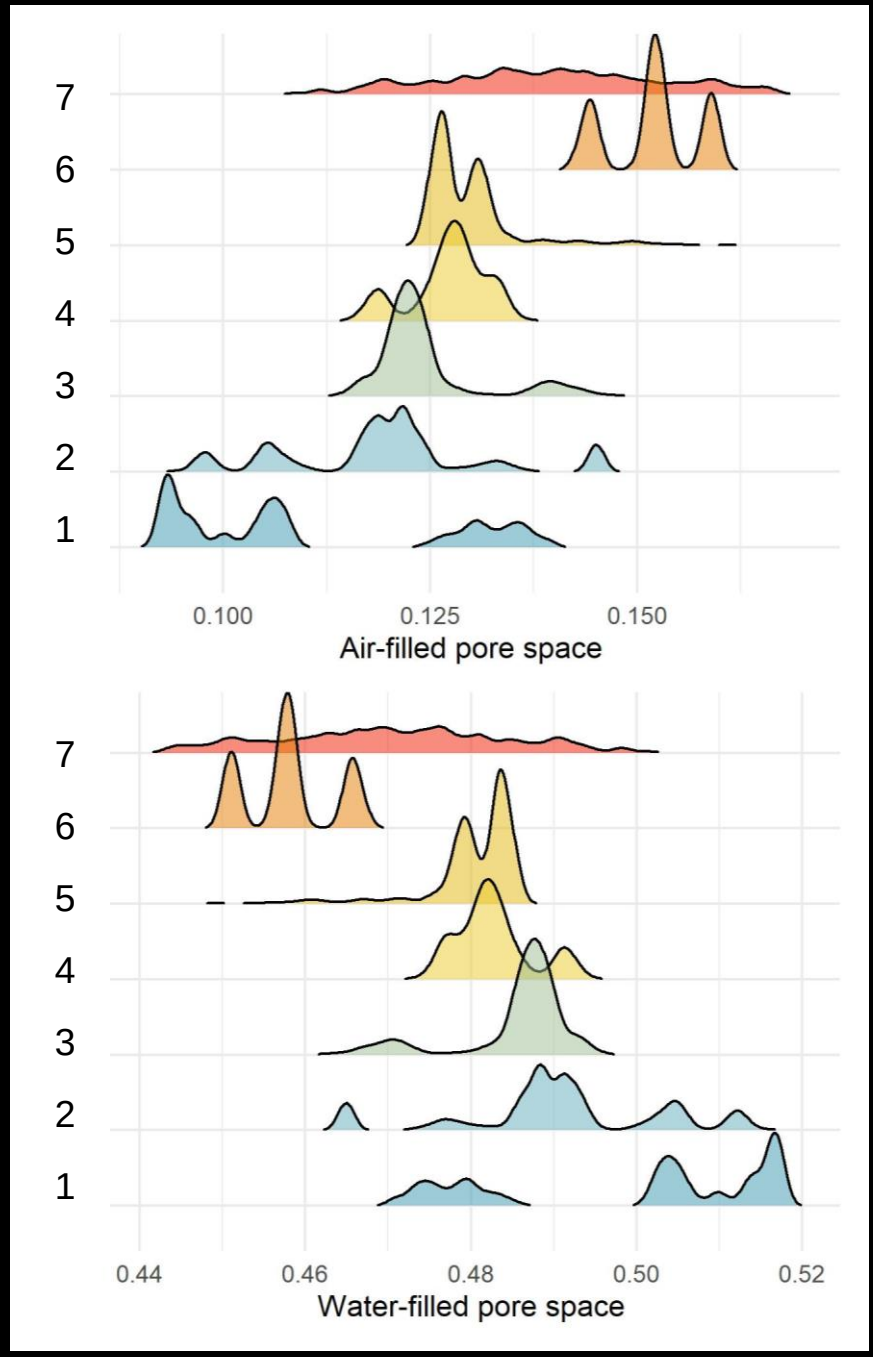
(CalcPTF)

Version 3.0

Andrey K. Guber, Yakov A. Pachepsky

Environmental Microbial and Food Safety Laboratory

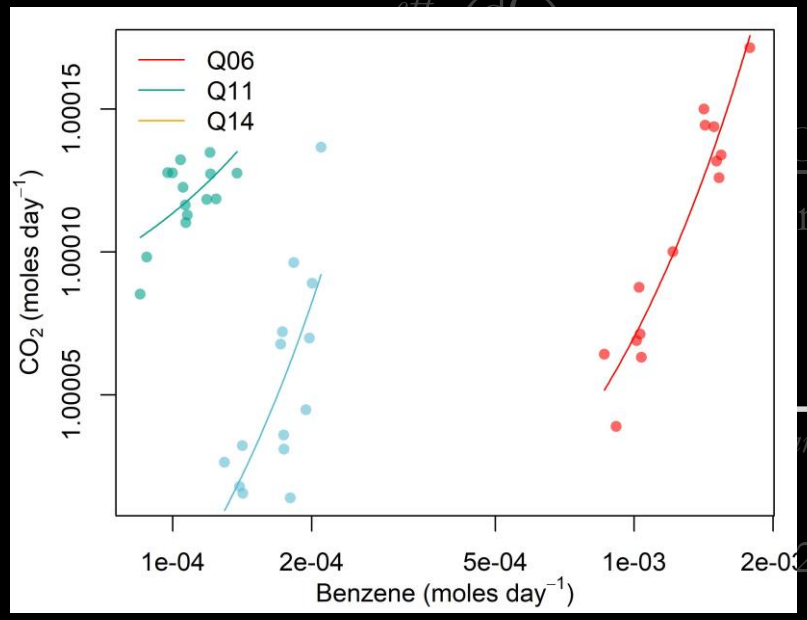
Beltsville Agricultural Research Center, USDA-ARS

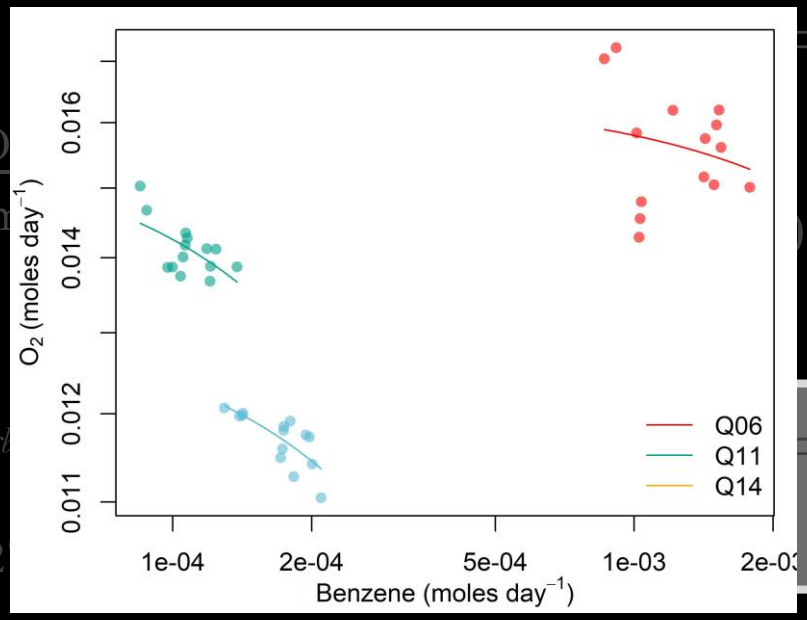


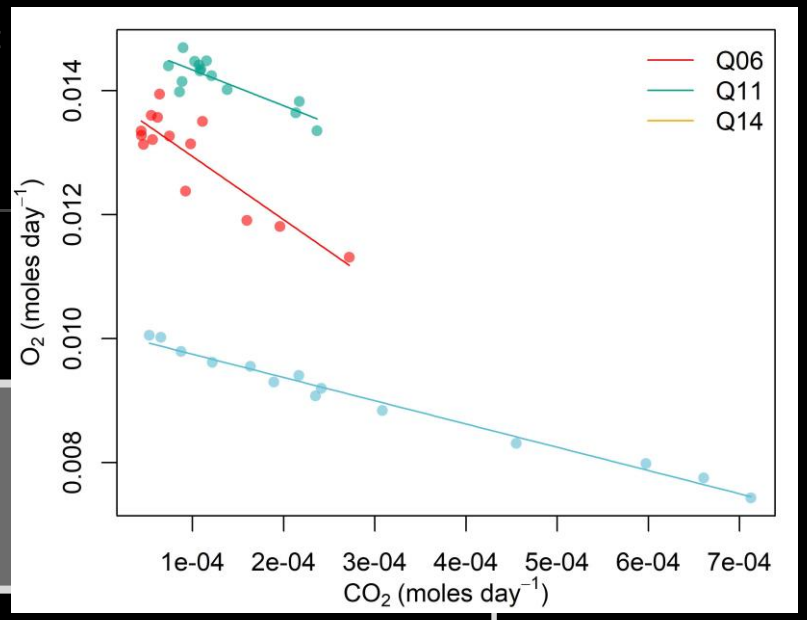
Guidance values

Convert Flux to Hydrocarbon Depletion (GUIDANCE)

CONVERT FLUX TO HYDROCARBON DEPLETION (SITE-SPECIFIC)







$$\text{Molar Ratio} = \frac{78.11\,\frac{gC_6H_6}{mol}}{44.11\,\frac{gCO_2}{mol}} \quad 2\ mol_{C_6H_6}$$

Ratio	Guidance (mass)	Site-specific (mass)
C_6H_6:CO_2	0.296	0.329
C_6H_6:O_2	0.325	0.179
C_6H_6:CH_4	1.038	1.038

Adapted from CRC CARE 2018

Convert Flux to Hydrocarbon Depletion (GUIDANCE)

CONVERT FLUX TO HYDROCARBON DEPLETION (SITE-SPECIFIC)

$$J = D_v^{eff}\left(\frac{dC}{dZ}\right)$$

$$J = 3.8 \times 10^{-7}\,\frac{m^2}{s}$$

$$J = 2.43 \times 10^{-}$$

Convert to g – *Repre*

$$2C_6H_6 + 15O_2 \rightarrow 12$$

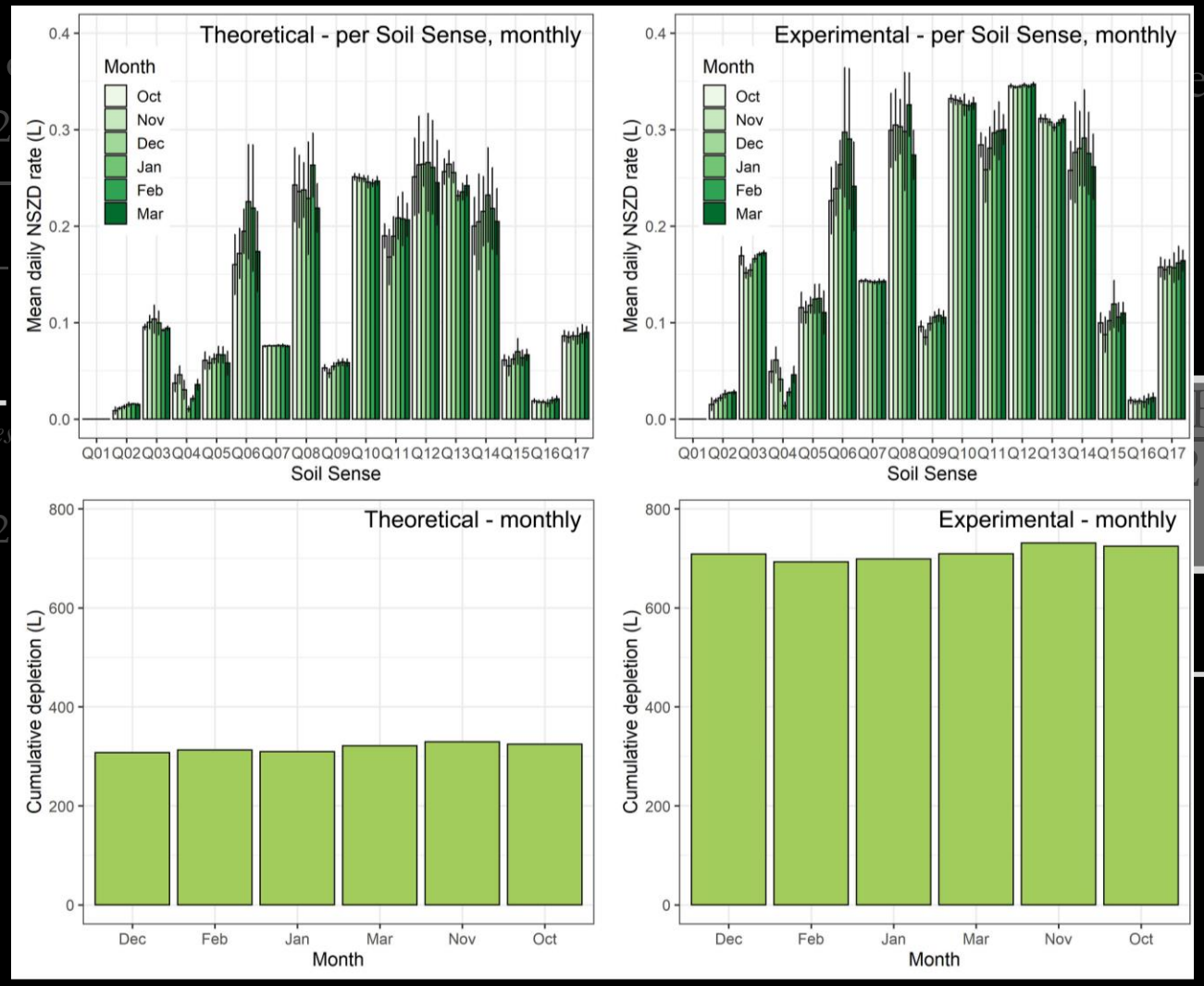
$$\text{Molar Ratio} = \frac{78.11\,\frac{gC_6H_6}{mol}}{44.11\,\frac{gCO_2}{mol}}$$

ed * Molar Ratio

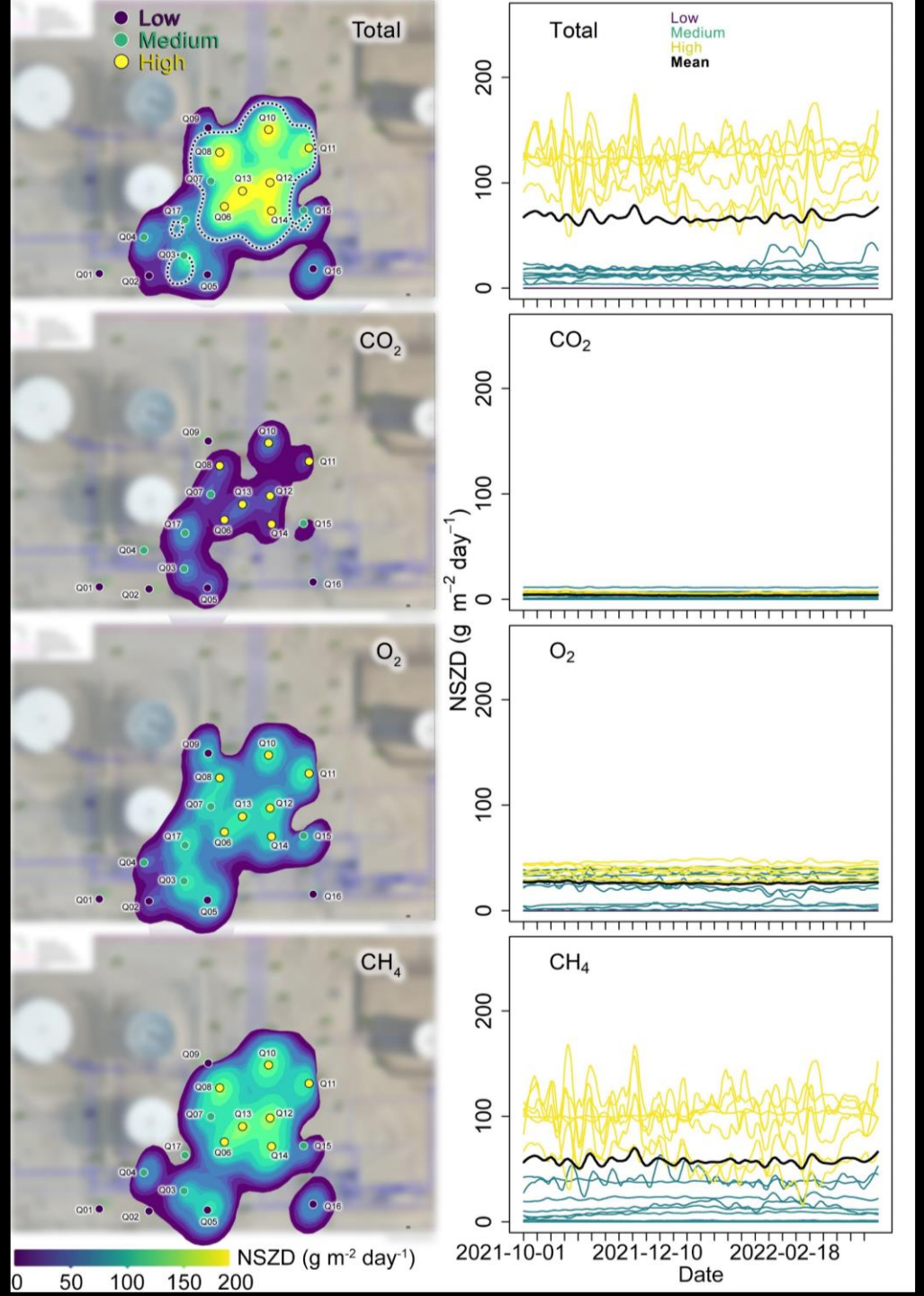
* 0.3 * 86400

H_6

d

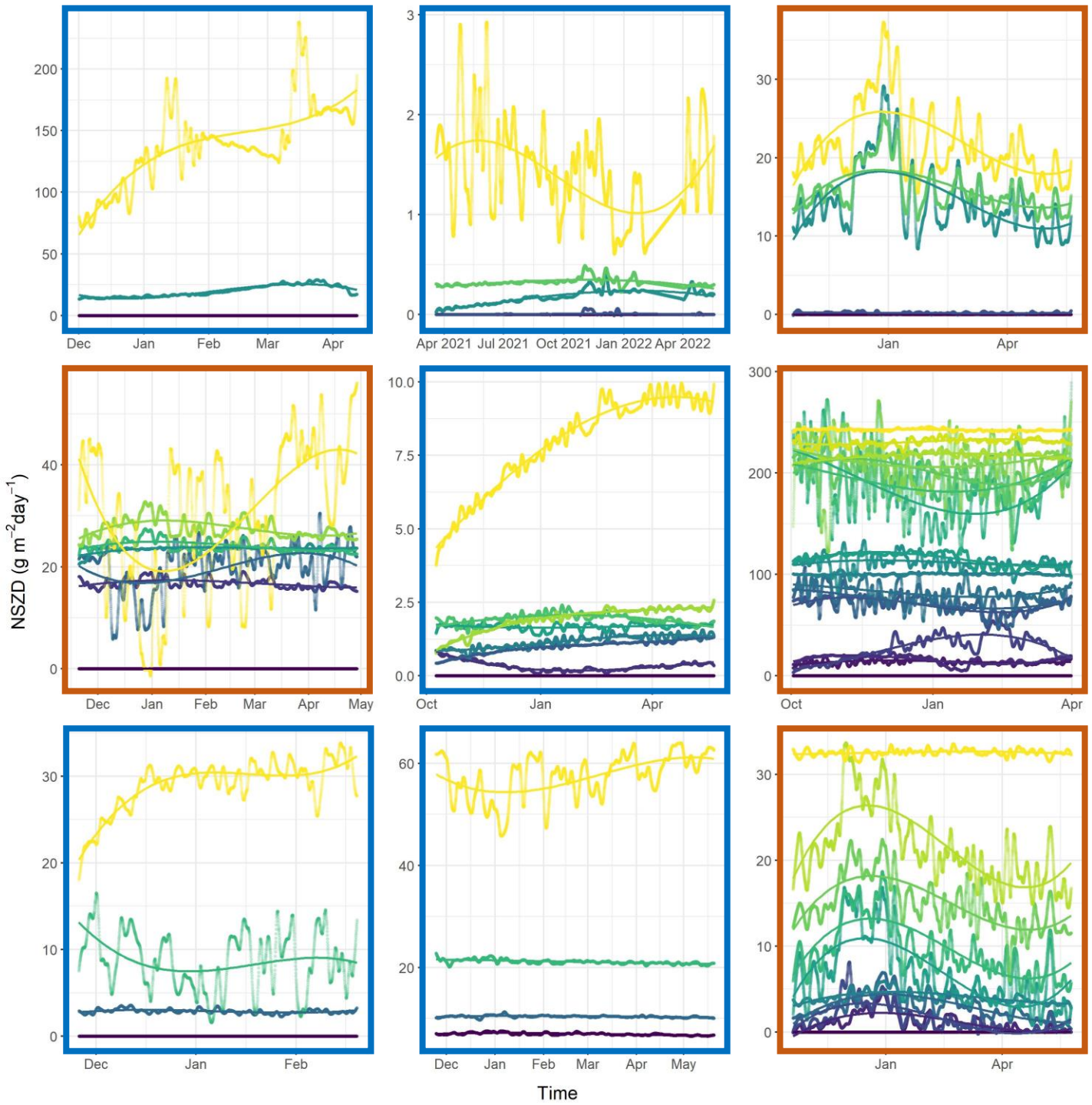


Adapted from CRC CARE 2018



NSZD through space

- NSZD estimates incorporate methane and paired CO_2 production/O_2 consumption
- More representative estimates of biological activity.

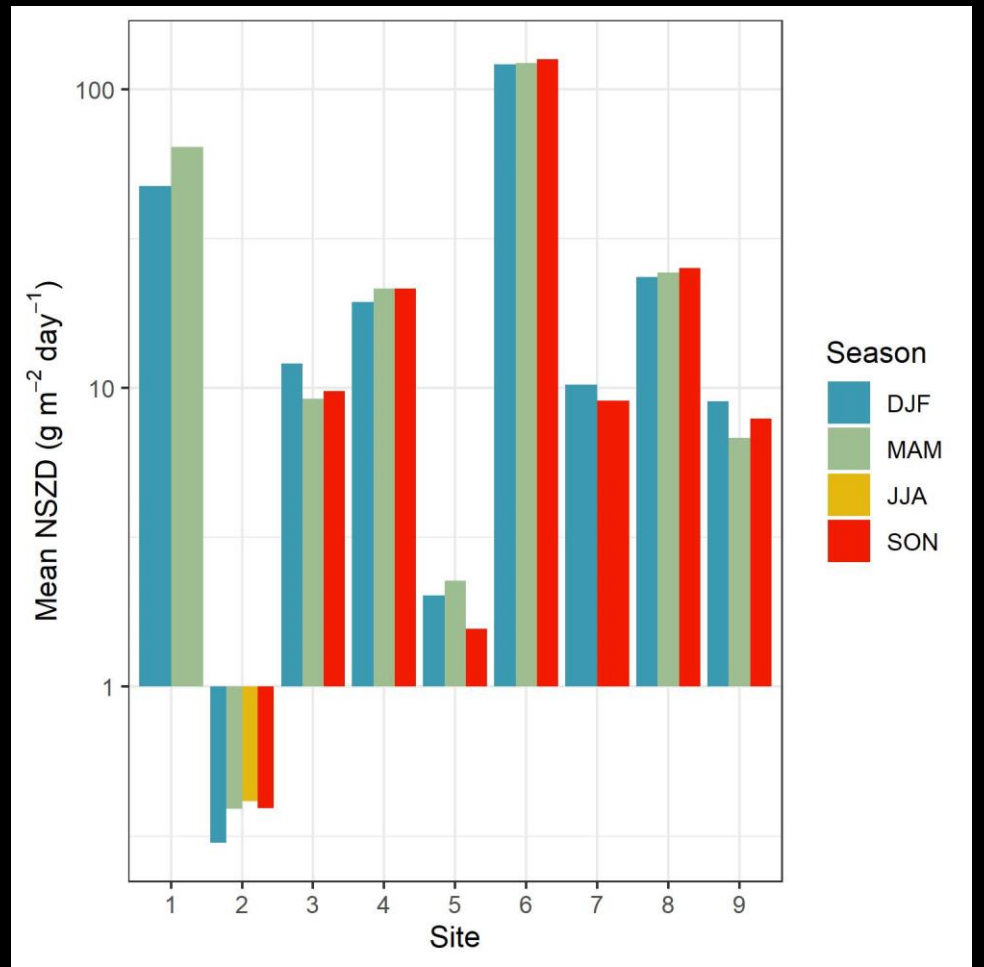


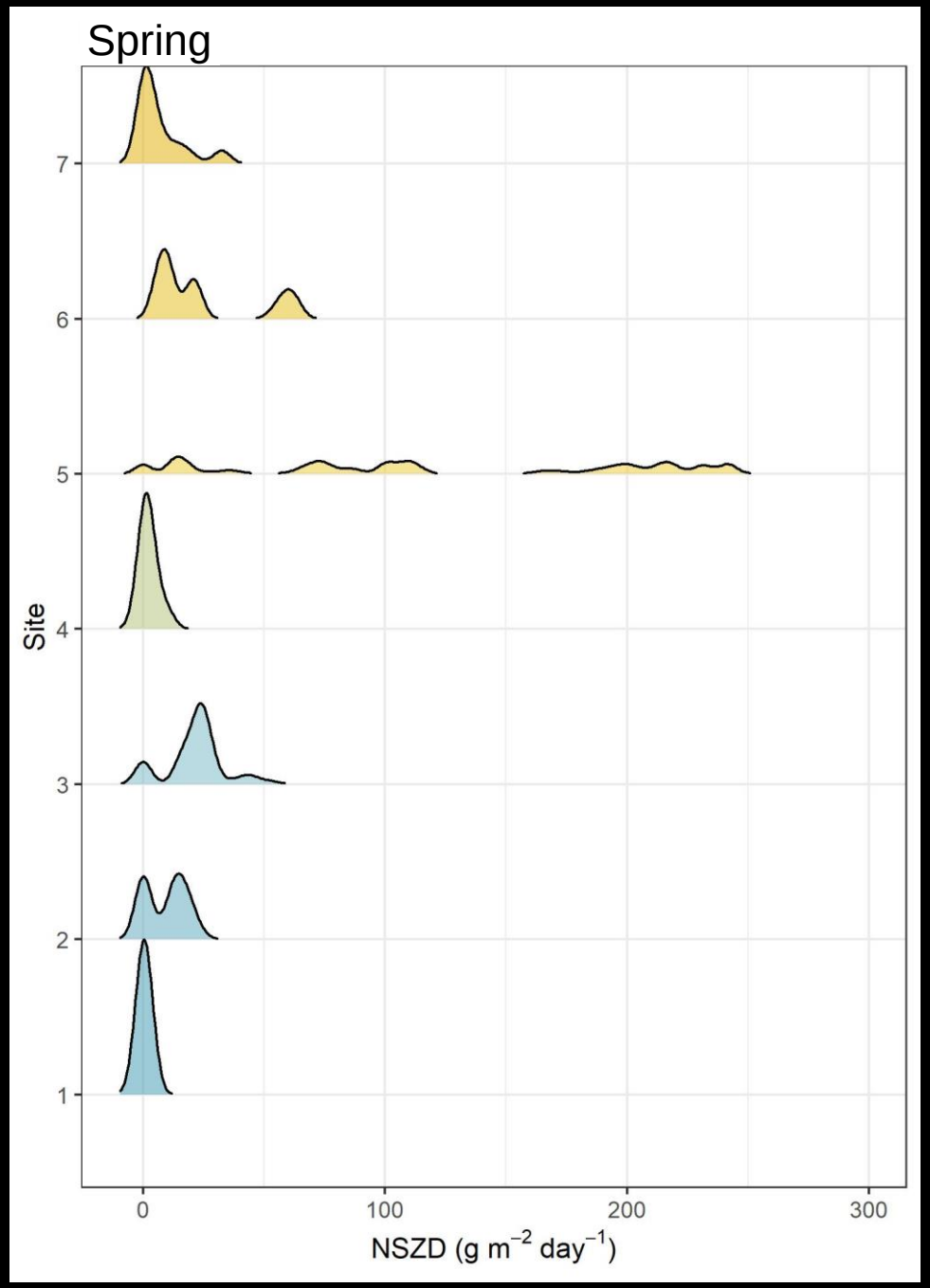
9 sites

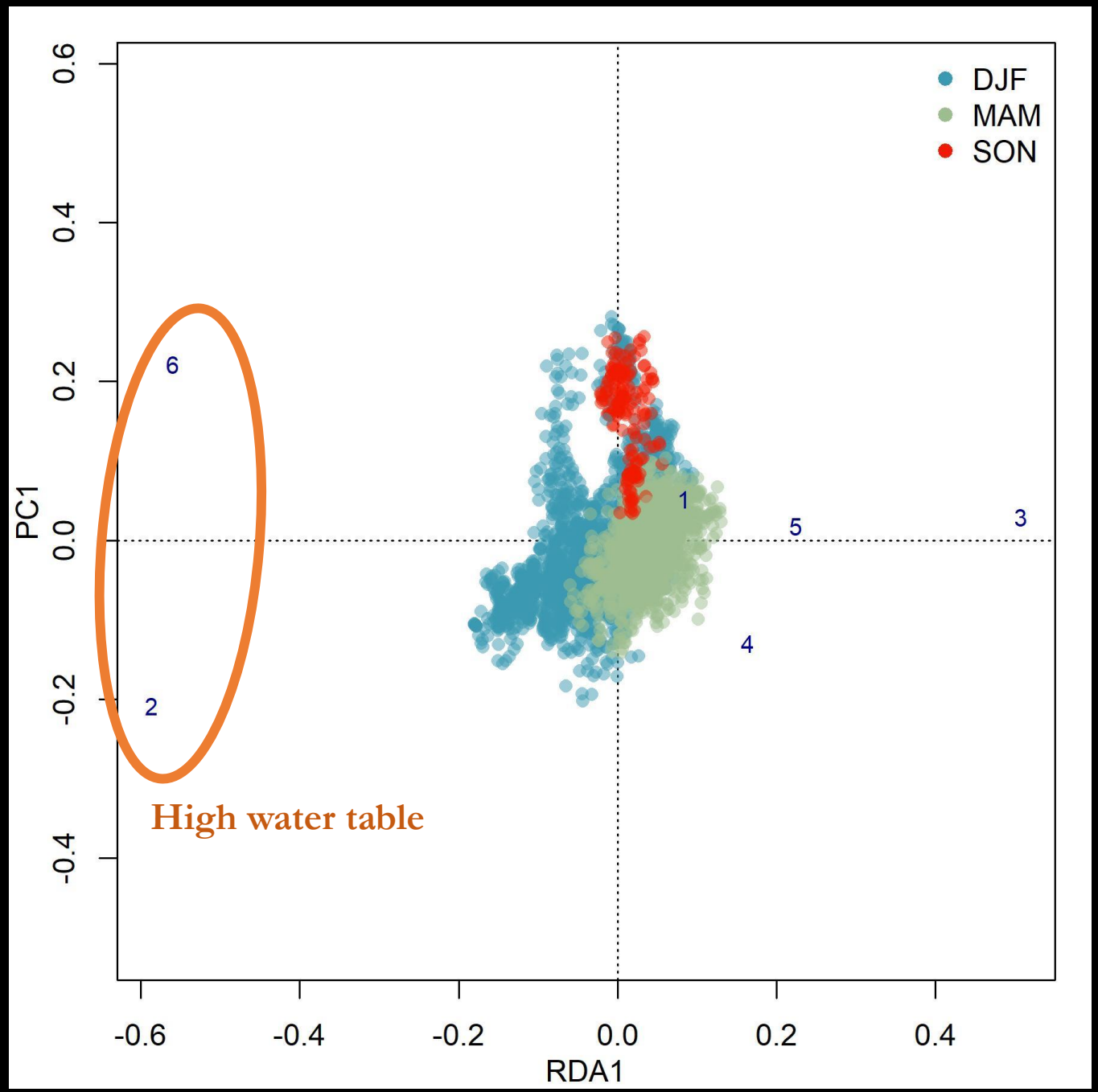
70 Soil Senses

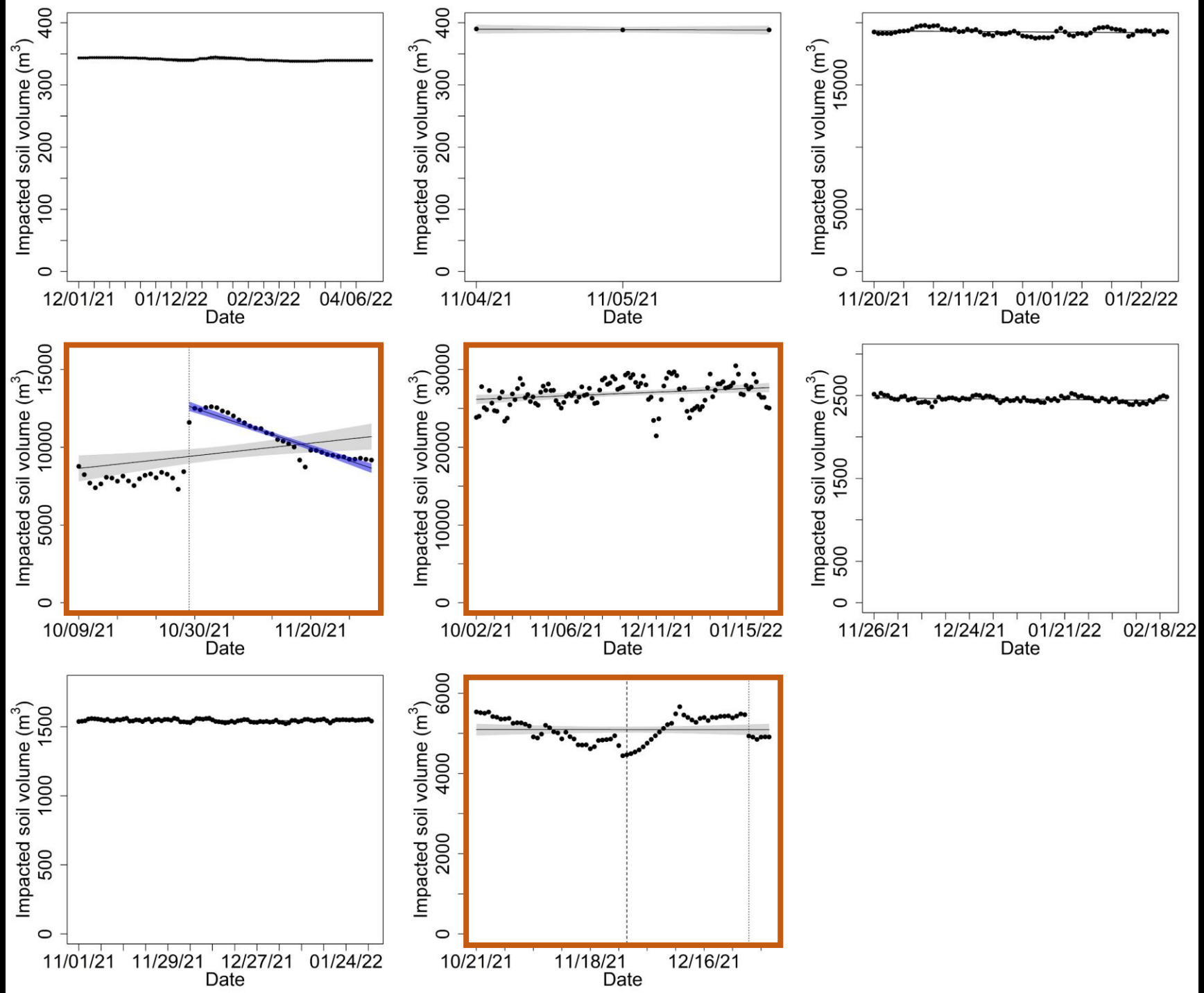
210 Sensor packs

59,877,180 data points!




Spring
Site
7
6
5
4
3
2
1
0
100
200
300
NSZD (g m^{-2} day^{-1})

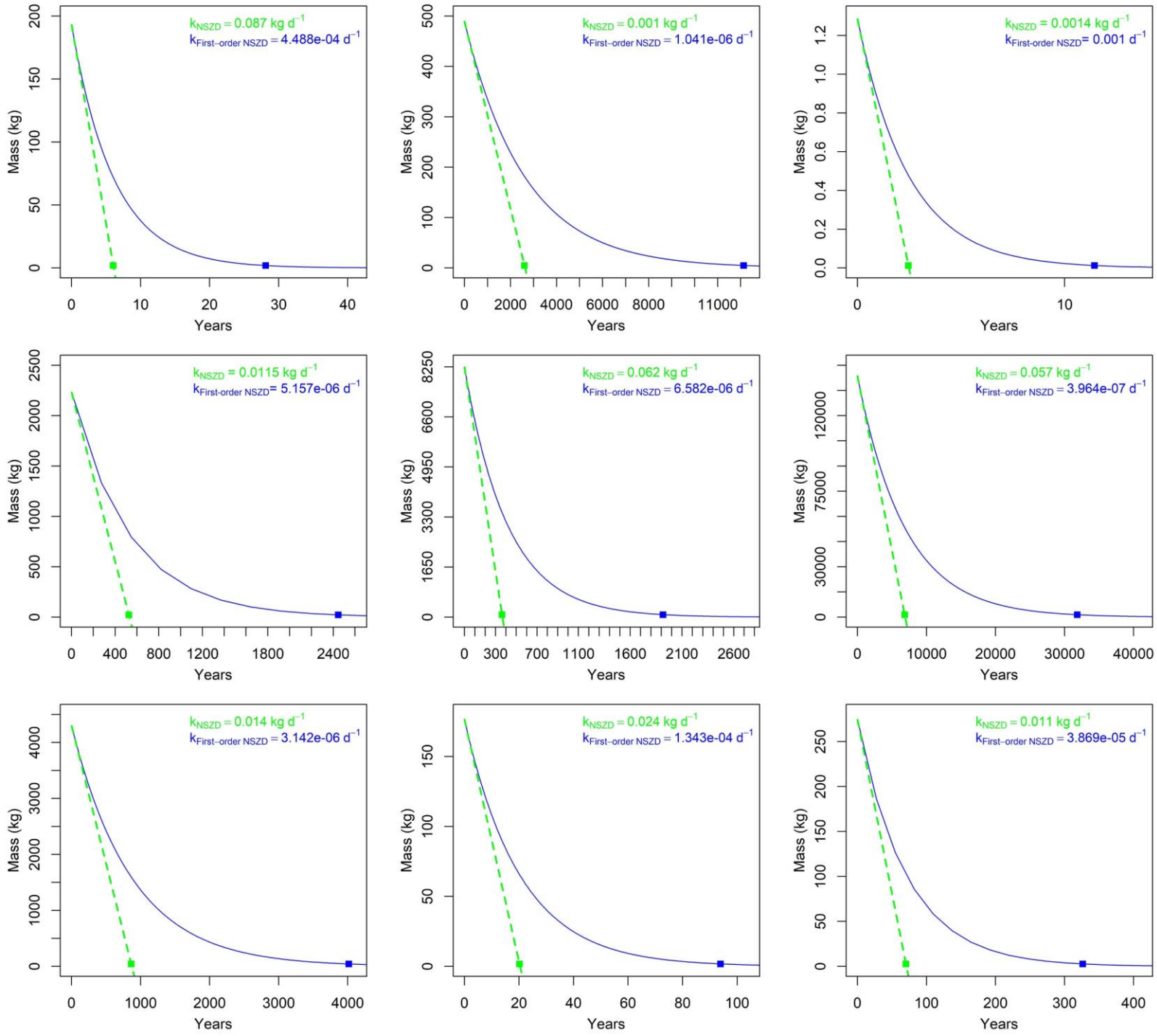

DJF
MAM
SON
PC1
RDA1
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.4
-0.2
0.0
0.2
0.4
6
1
5
3
4
2
High water table



Plume volume

Typically stable over seasons

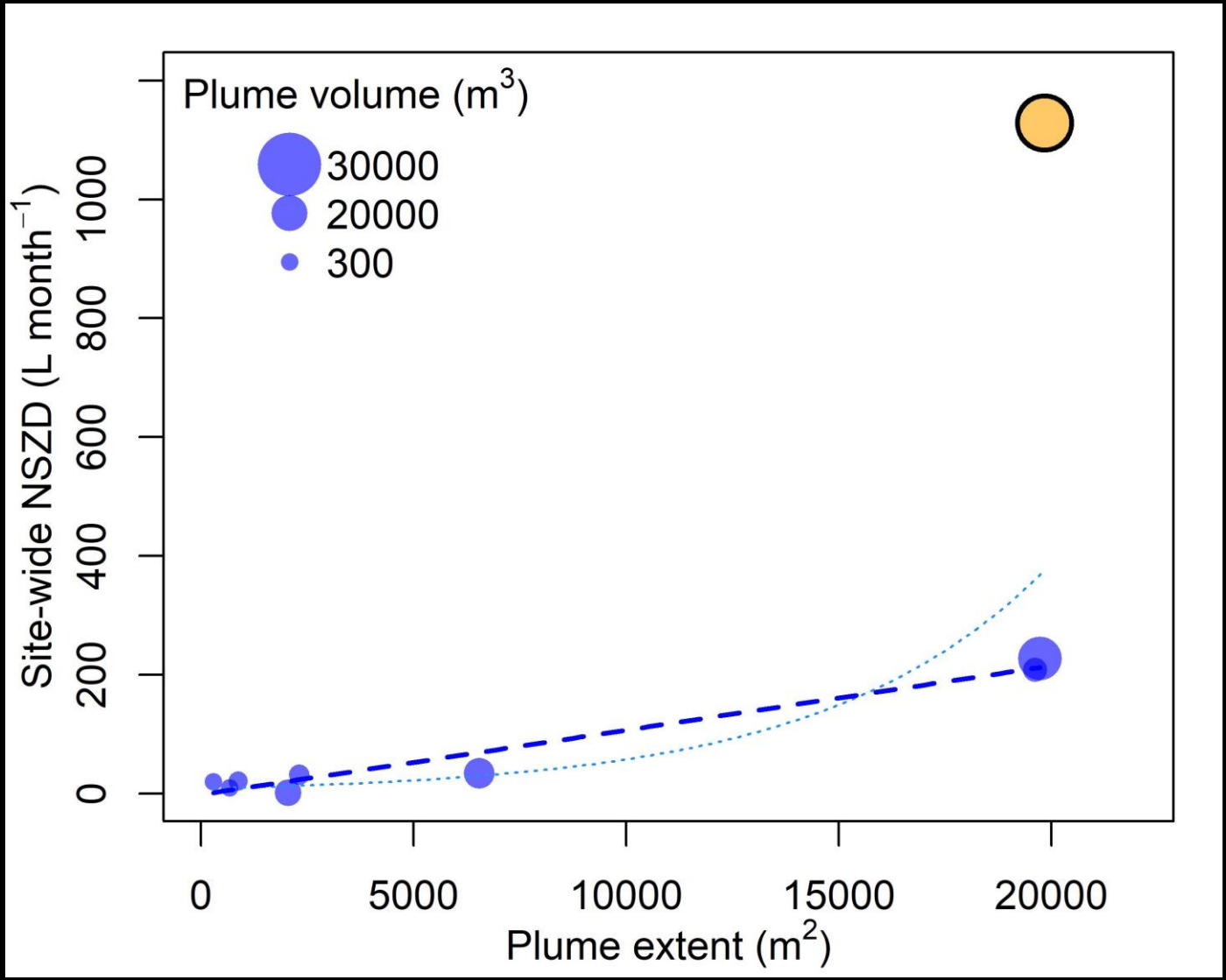
- Active site
- Additional sensor install and equilibration
- Site with organic soils and fall freeze-up + animal visitors.



Closure estimates

- Zero-order are "optimistic"
- TTC depends on PHC mass and biological activity.

How do sites compare?



Interactive, real-time visualization and rankings

How is my site doing today?

How does my site compare to others?

Interactive Machine Learning to optimize site management

Where is the best place for my sensors?

Should I add more sensors?

Do I still need to sample groundwater?

Interactive machine learning to optimize site management

Where is the best place for my sensors?

Should I add more sensors?

Do I still need to sample groundwater?

Where are we now?

- High density continuous measurements
  - Diurnal and seasonal nuances, site-driven variation
  - CH_4 may make up the bulk of NSZD in some sites
- Soil moisture
  - Implications for fluid transfer and PHC distributions
- Site-specific estimates
  - Theoretical stoichiometry may not represent site processes
- Stay-tuned for next year!
  - FEA
  - Bayesian prediction networks
  - Carbon sequestration
  - Winter is coming.

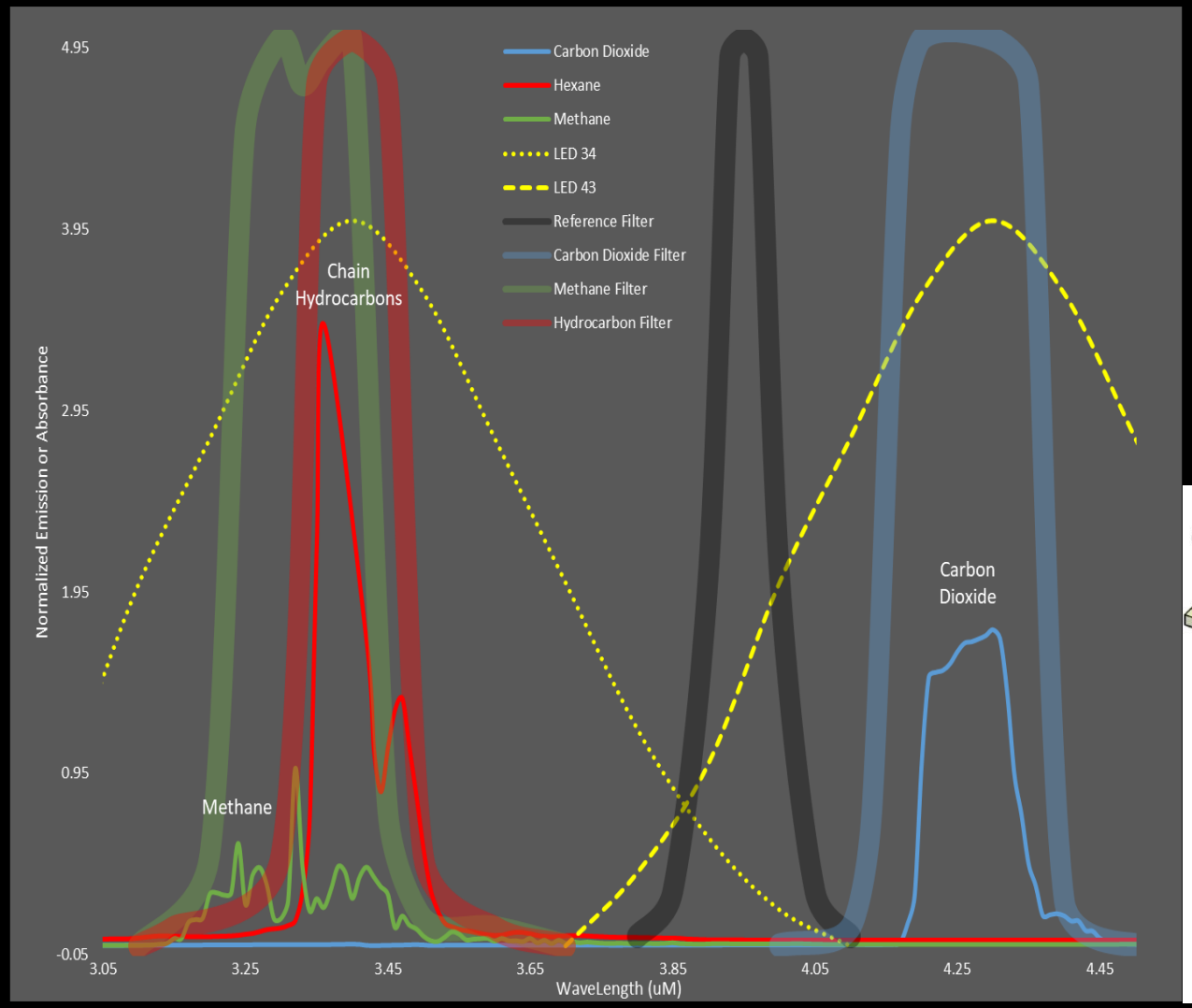
Check us out at booth #12!

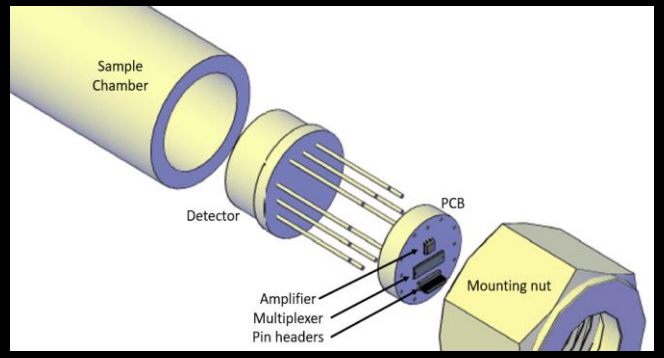
Thank you!

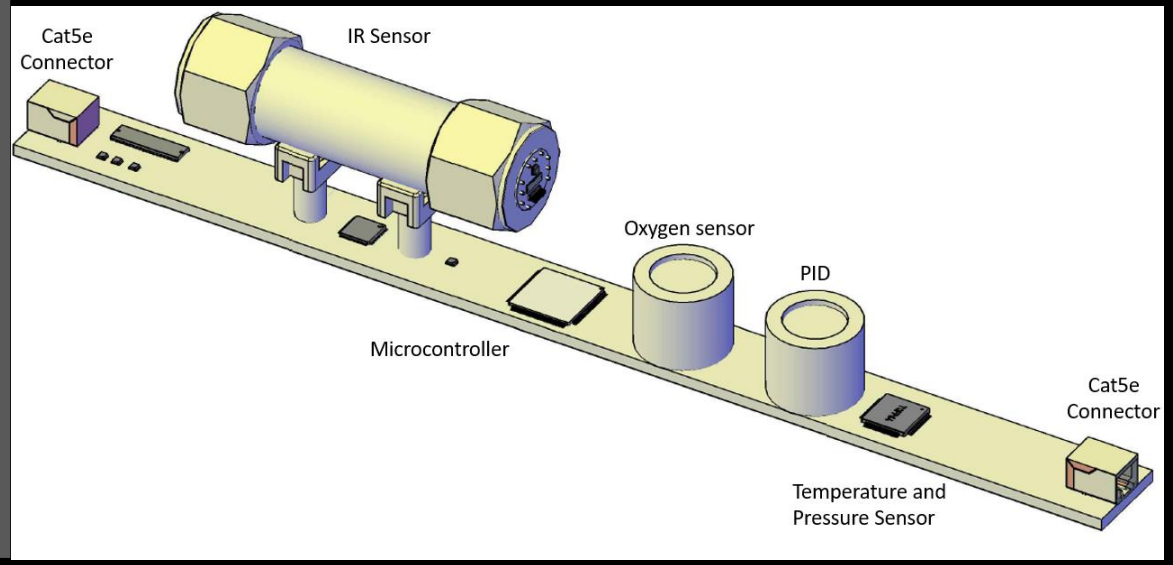
SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA

TECHNOLOGIES DU DEVELOPPEMENT DURABLE CANADA

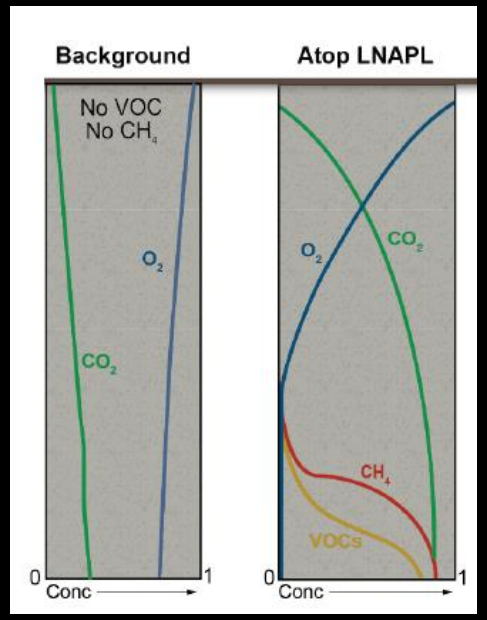
Pyroelectric Infrared Detectors in Soil Sense



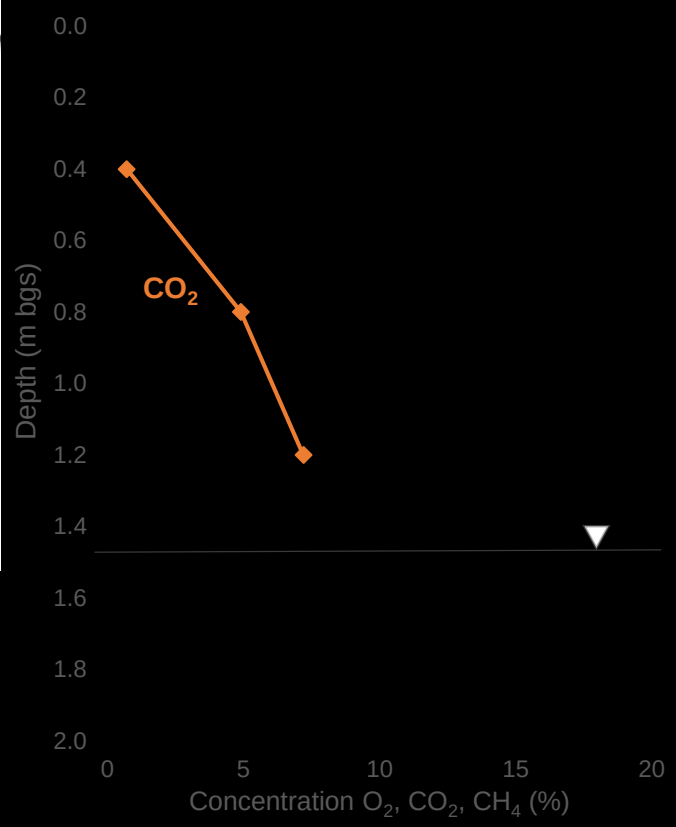




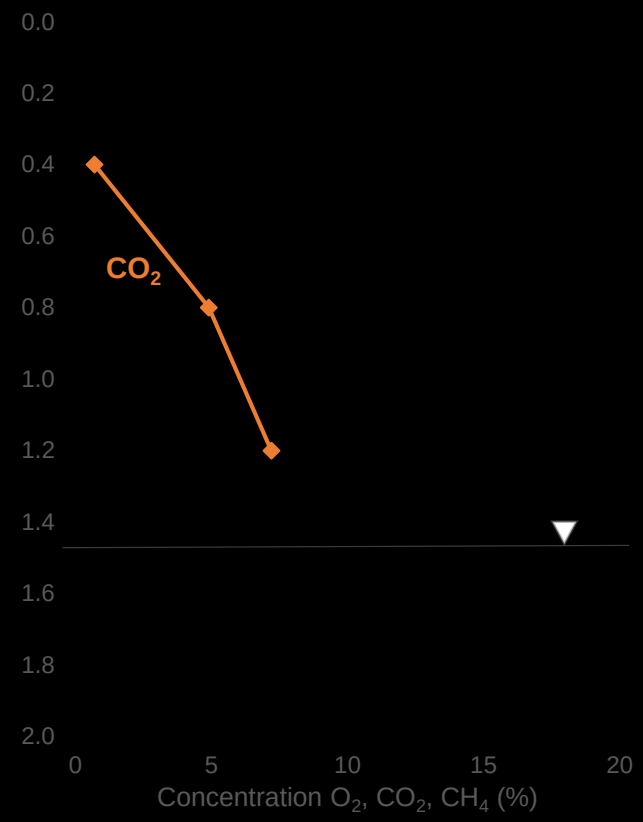
CONCENTRATION GRADIENT METHOD ("CGM") – CLASSIC SITE



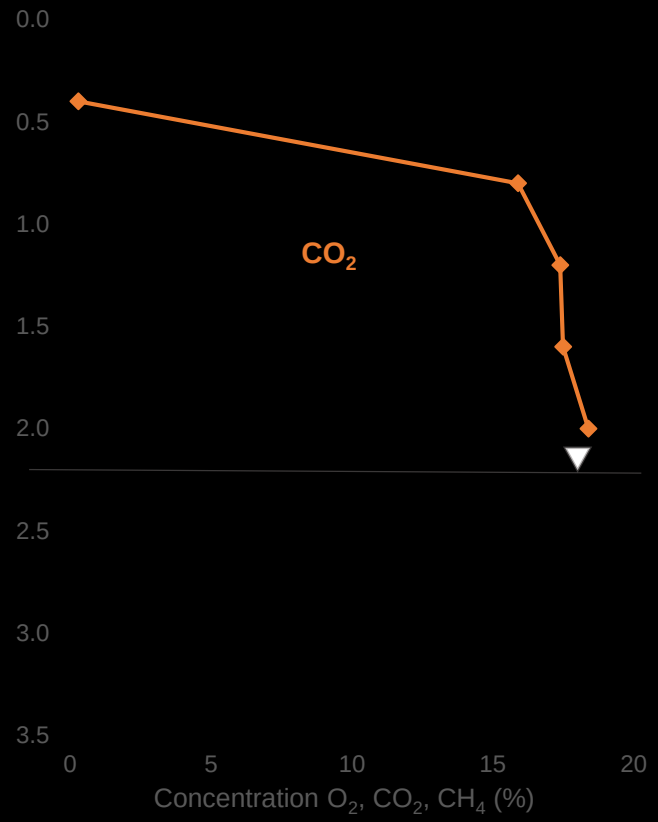
Background



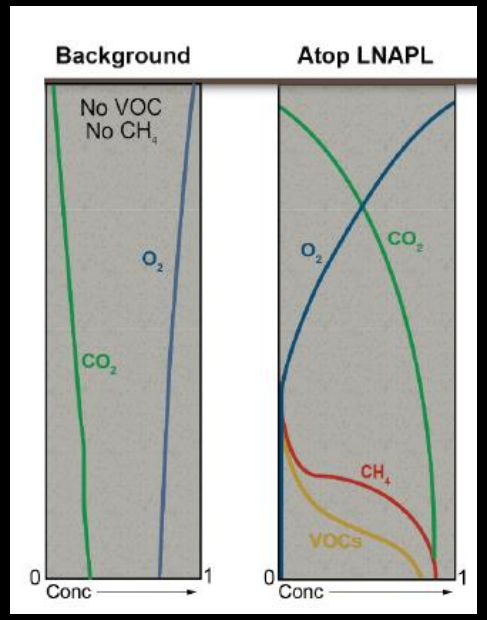
Source 1

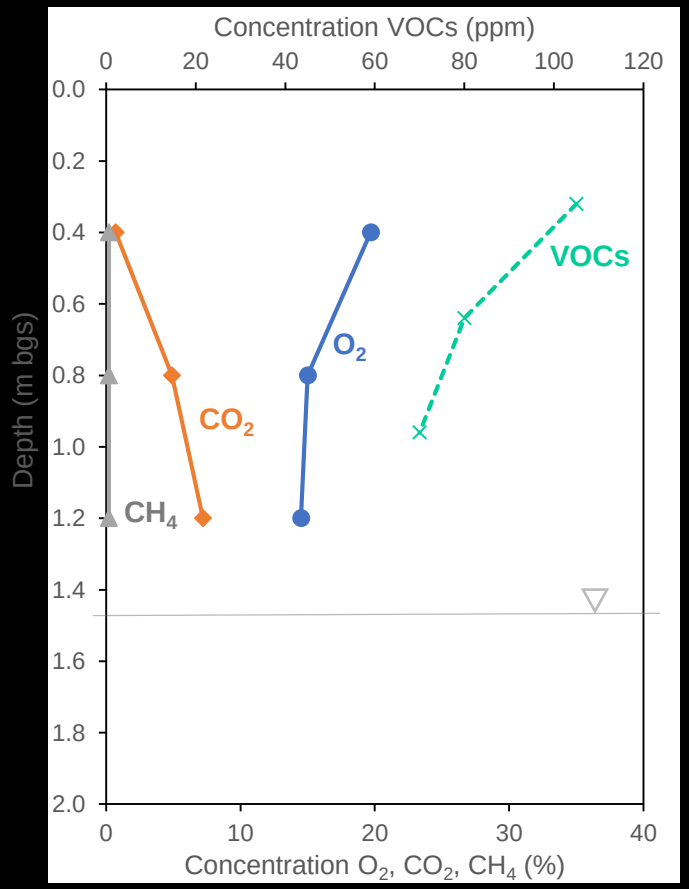


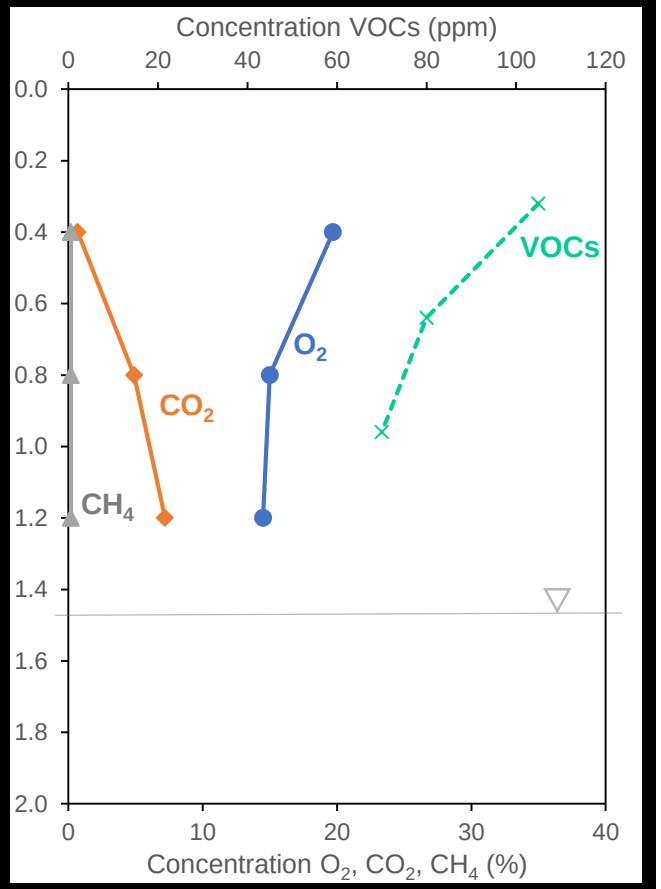
Source 2

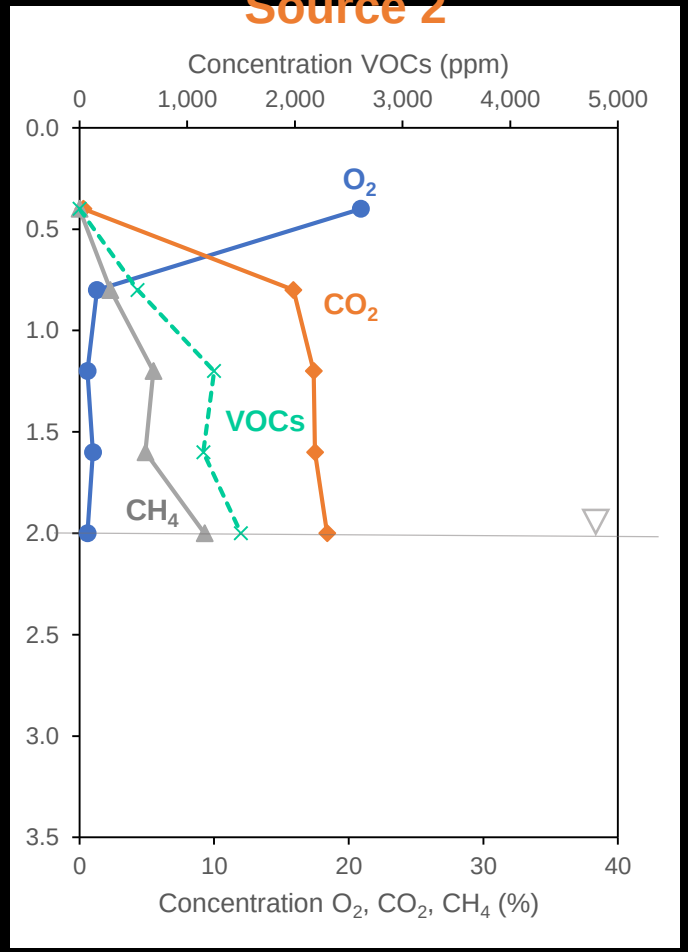


Concentration Gradient method ("CGM") – classic site

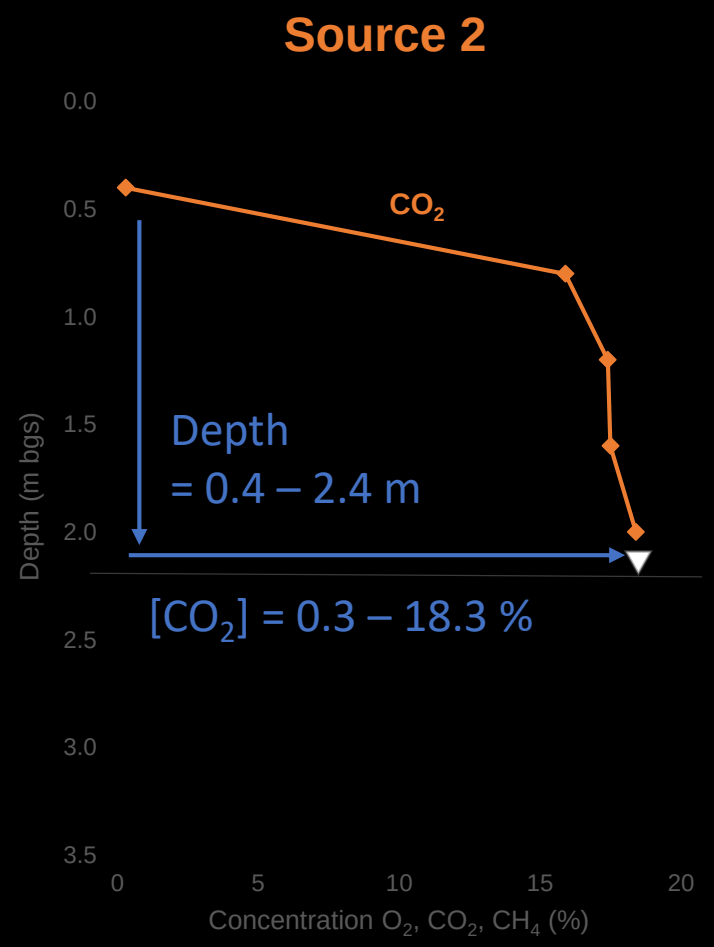






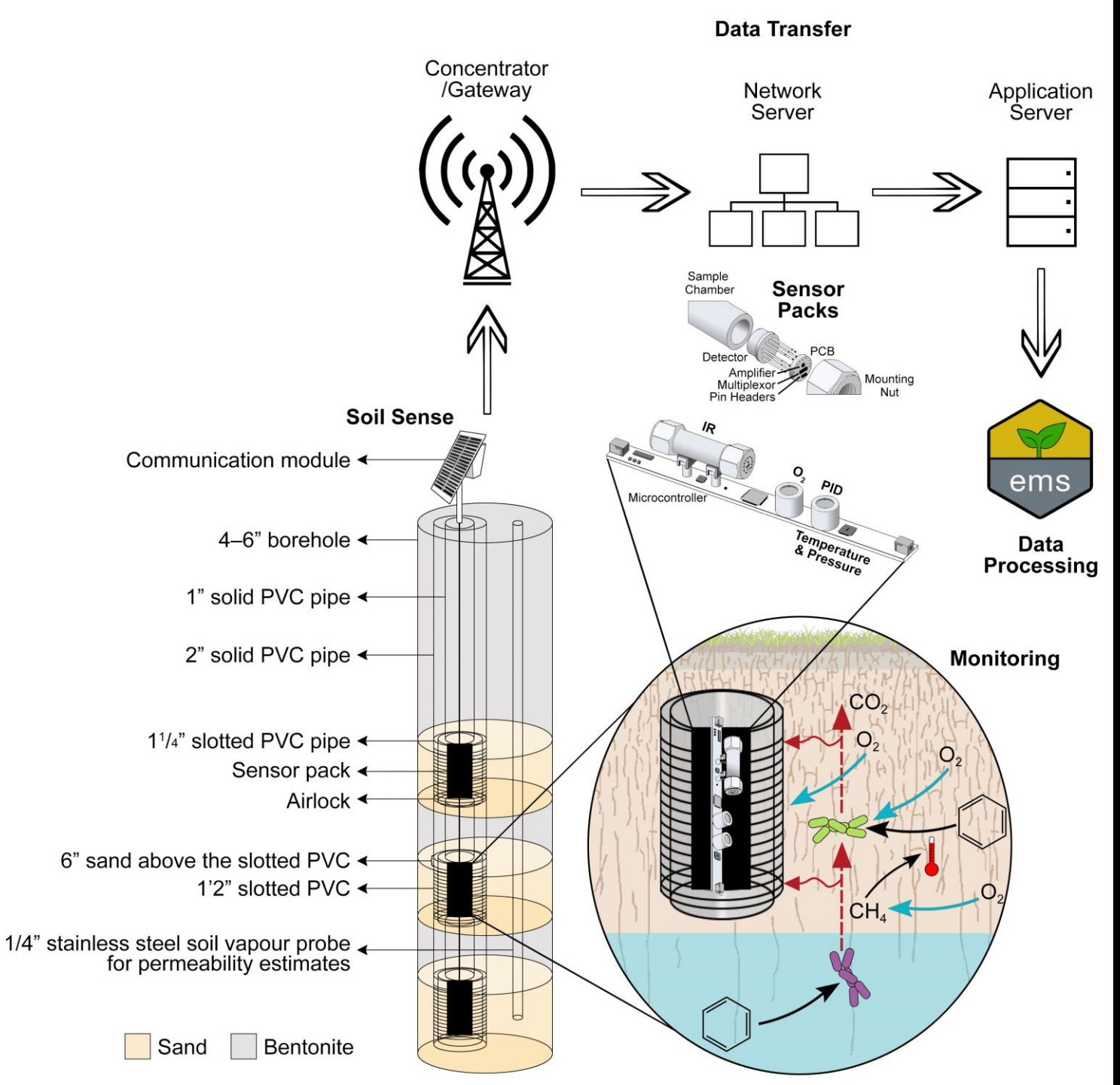


CGM – Step 1: Calculate Flux from Soil



CGM– Step 2: Convert Flux to Hydrocarbon Depletion (GUIDANCE)

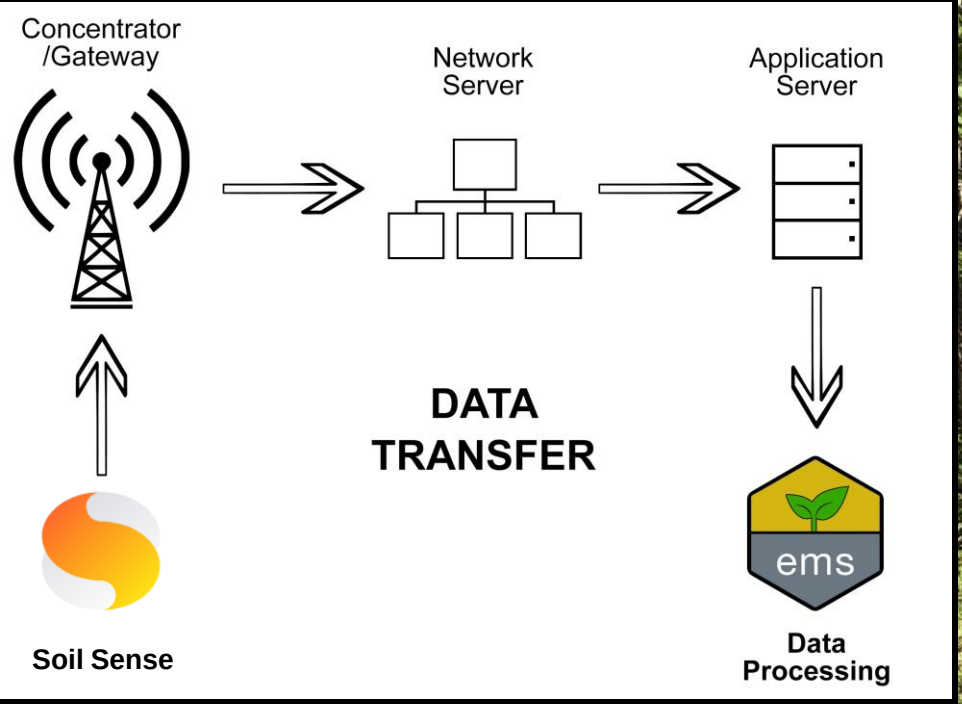
$$= 0.63 \ \frac{g_{C_6H_6}}{m^2 d}$$



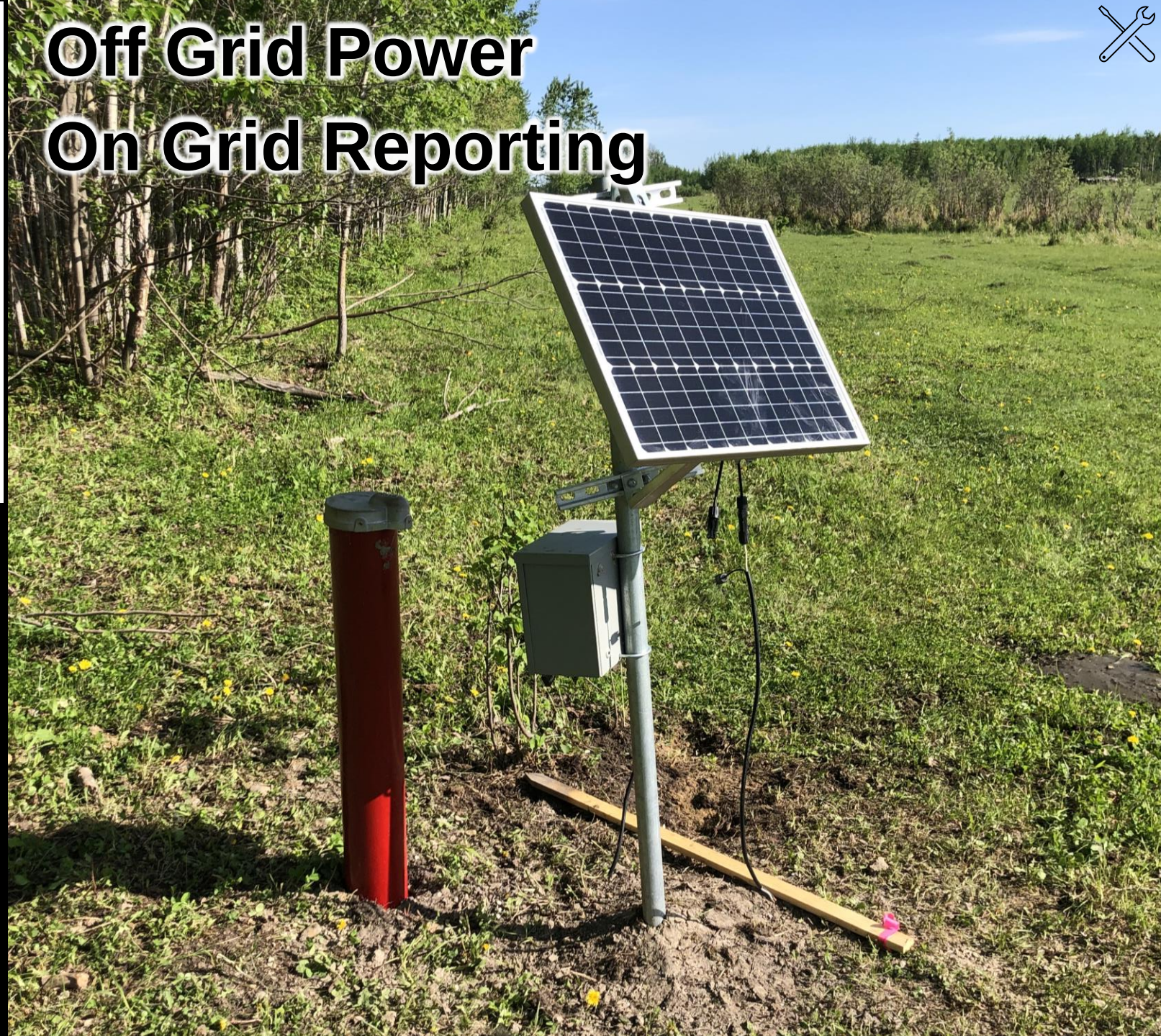
EMS Soil Sense

Every 30 Minutes
All day, every day

Product description



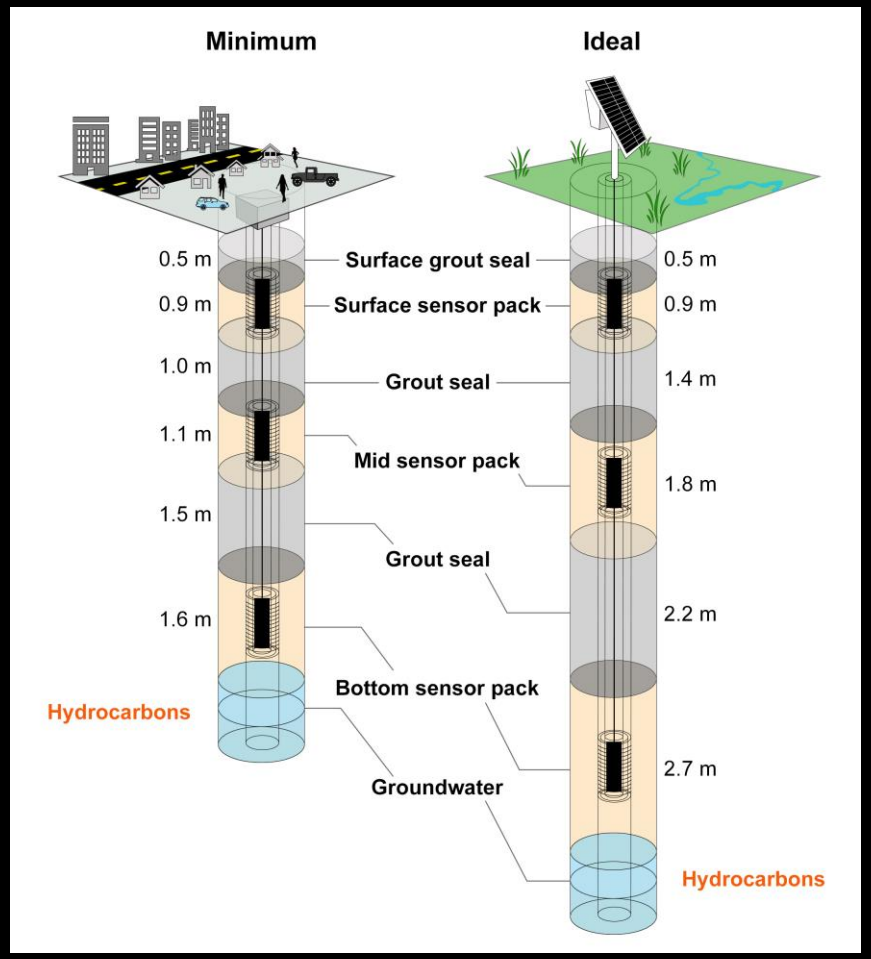
Off Grid Power
On Grid Reporting



Vertical placement parameters

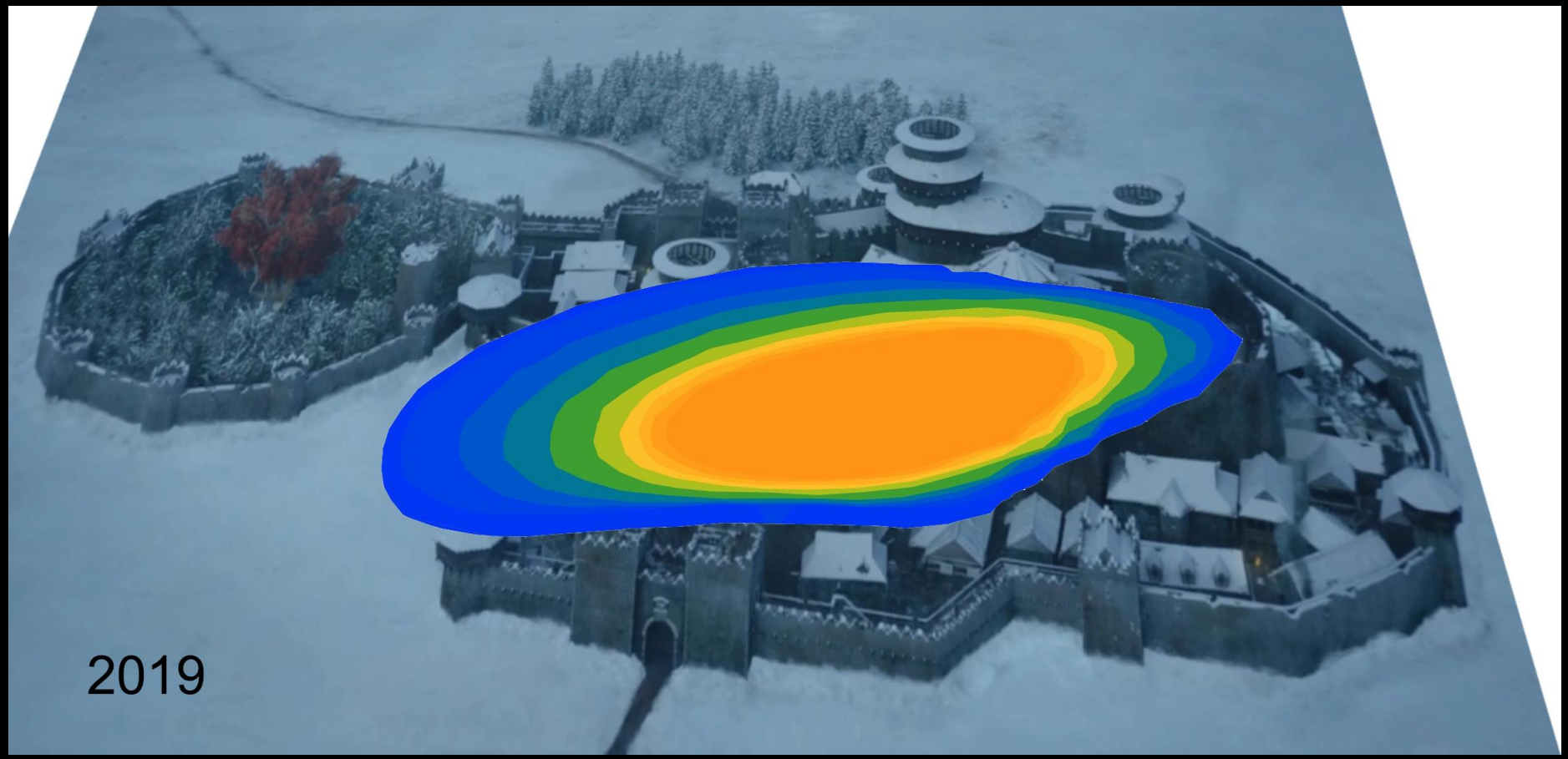
EMS SOIL SENSE

Design flexibility



Old dragon rendering Facility

Old dragon rendering Facility



Old dragon rendering Facility