Environmental Field Studies

Topic 3: Real-world leakage assessment

Katherine Romanak

Funders and Collaborators

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Nick Hudson and Rob Heath- CTSCo

Paul Jensen - ALS Geochemistry

JP Nicot – Bureau of Economic Geology

David Bomse - Mesa Photonics

Gulf Coast Carbon Center

anlecr&d Australian National Low Emissions Coal Research & Development

COAL21 Low Emissions Coal Australia

CTSCo Carbon Transport and Storage Company

GCCC Gulf Coast Carbon Center

Proposed CTSCo Surat CCS Demonstration Project

- Total of 180,000 tonnes CO_2 captured from the Millmerran Power Station in southeastern Queensland.
- Stored over 3 years in the low salinity groundwater of the Precipice Sandstone
- Storage site 21 km SW of Wandoan, Queensland at Glenhaven

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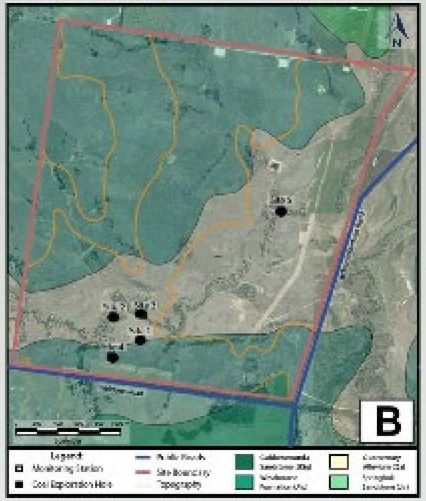
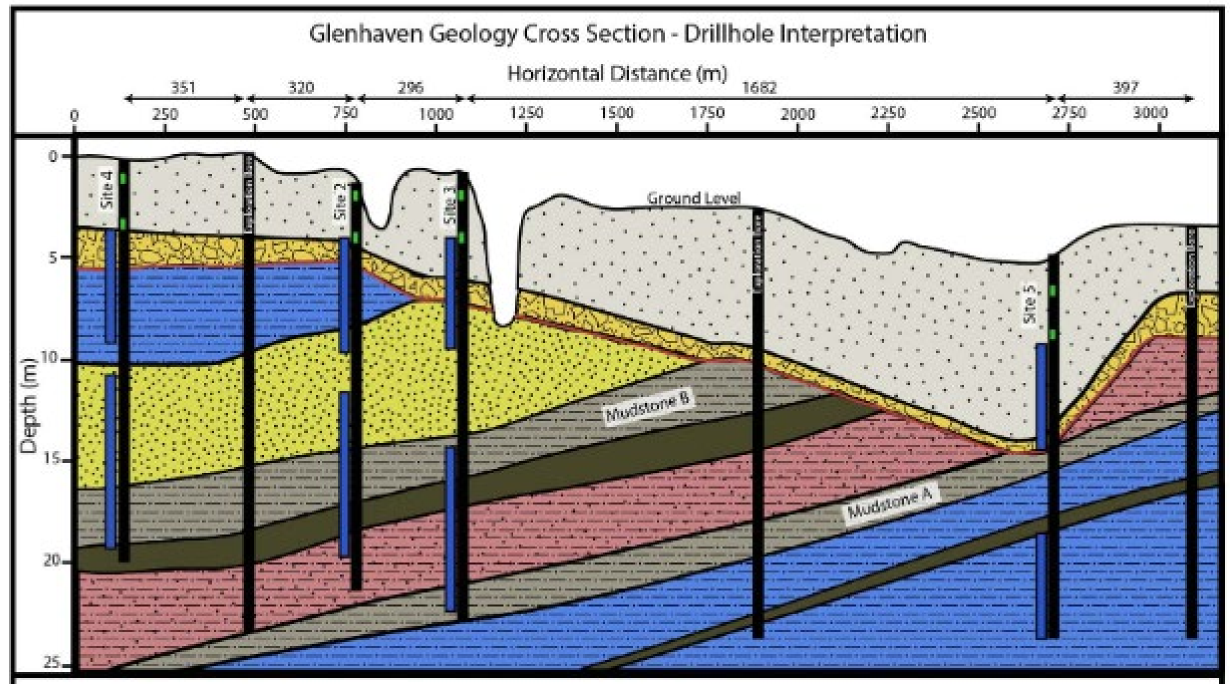
Environmental Monitoring Infrastructure

- 5 monitoring stations
  - 1 weather station
  - 4 soil gas stations (1- & 5-m depths)
  - 4 groundwater stations (10- & 20-m depths)



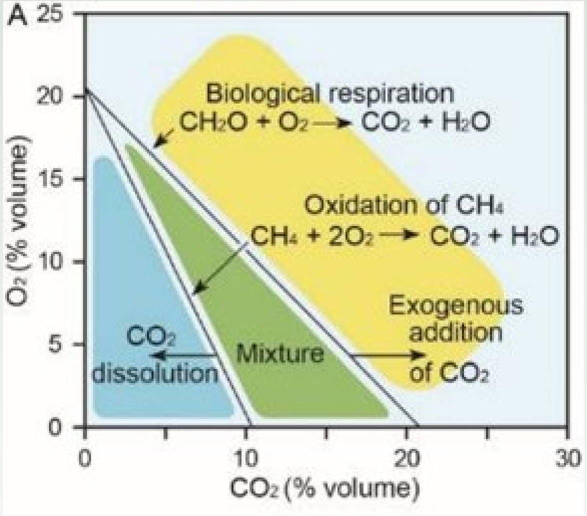
Siller et al., 2018 *Applied Geochemistry*, 96, pp.191-203.

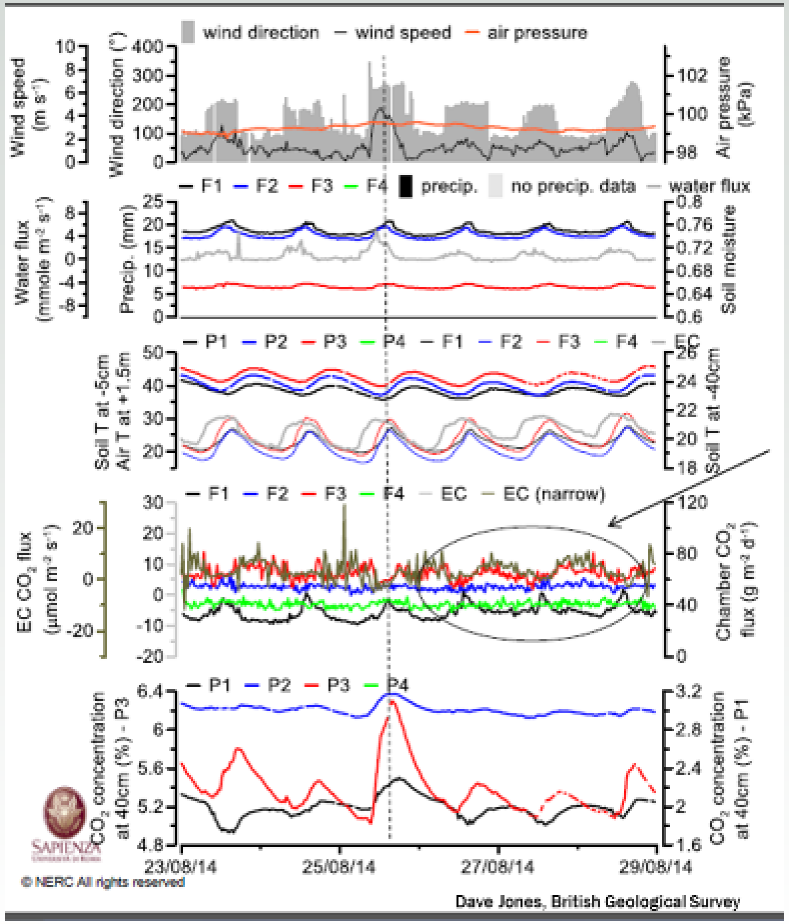


Siller et al., 2018, Applied Geochemistry Volume 96, Pages 191-203

BEG's Process-Based Approach

- 4 simple coexisting soil gases: CO_2, O_2,CH_4, N_2
- Stoichiometry of reactions to identify key processes.
- No need for years of background CO_2 measurements and weather data
- Universal leakage threshold
- Stakeholder friendly, simple, immediate





Romanak et al., 2014, International Journal of Greenhouse Gas Control, 30, 42-57
Romanak et al., 2012, Geophysical Research Letters, *39* (15).

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Two Related Field Studies for Advancing a Process-based Approach

1. *Optimizing a process-based approach for near-surface leakage assessment*
2. *Isotopic characterization of source CO_2 and naturally occurring CO_2, Glenhaven*

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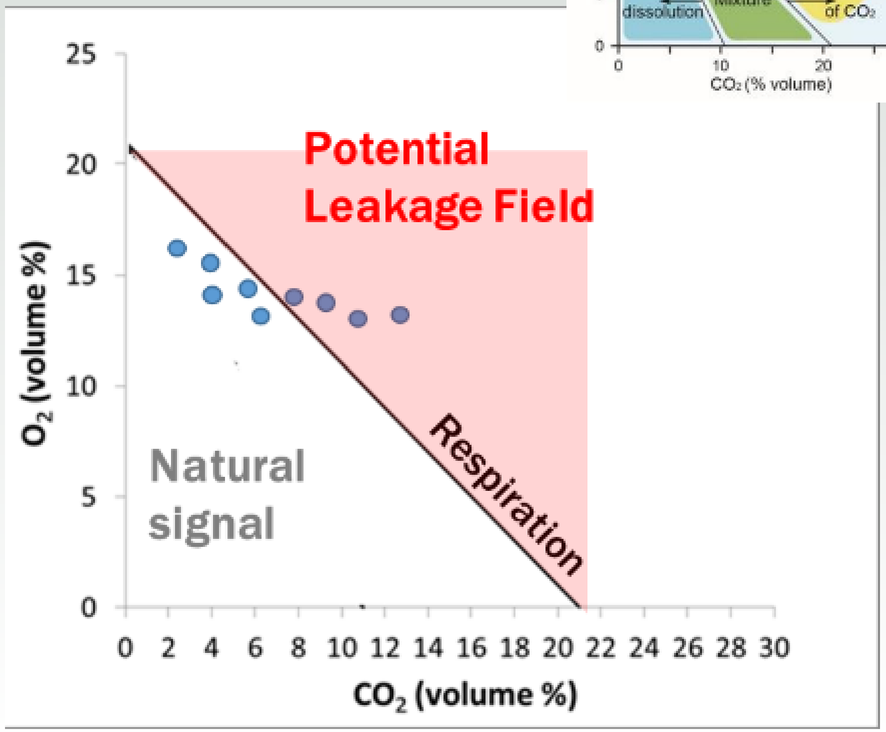
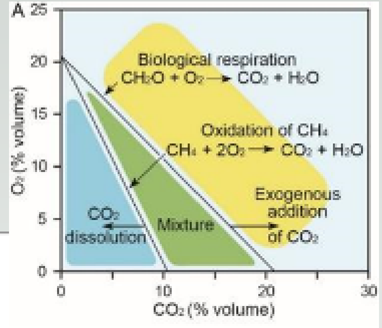
Two Parts to a Process Based Approach

#1
- Most assessments will indicate no anomaly (on or left of the respiration trend)

#2
- In the case where the respiration threshold is exceeded more assessment will be needed.





Problem Statement and Objectives

Increase the ease and accuracy of environmental M&V to support the successful industrial deployment of CCS

- Avoid false positives for leakage
- Respond to stakeholders concerns (e.g. Kerr Claim)
- Easily comply with regulation (e.g. Low Carbon Fuel Standard)

2019 TCCS-10 Trondheim Norway
https://www.youtube.com/watch?v=D2gWTeAdXjY


ghgt-15

15th International Conference on Greenhouse Gas Control Technologies GHGT-15

5th -8th October 2020, Abu Dhabi, UAE

Technical monitoring considerations for advancing CCS Projects under the California Low Carbon Fuel Standard and other global regulatory regimes

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First Project- 3 Main Deliverables

Optimizing a process-based approach for near-surface leakage assessment

1. **Attribution:**
   - Refine the process-based matrix for methane-rich sites. Current matrix fields are not rigorously tested in methane-rich soils.
2. **Quantification:**
   - A methodology for separating background surface emissions from leakage emissions will be tested.

- 3. Sensing:
  - Techno-economic assessment of currently available sensors and recommendations for advancements in real-time sensing.

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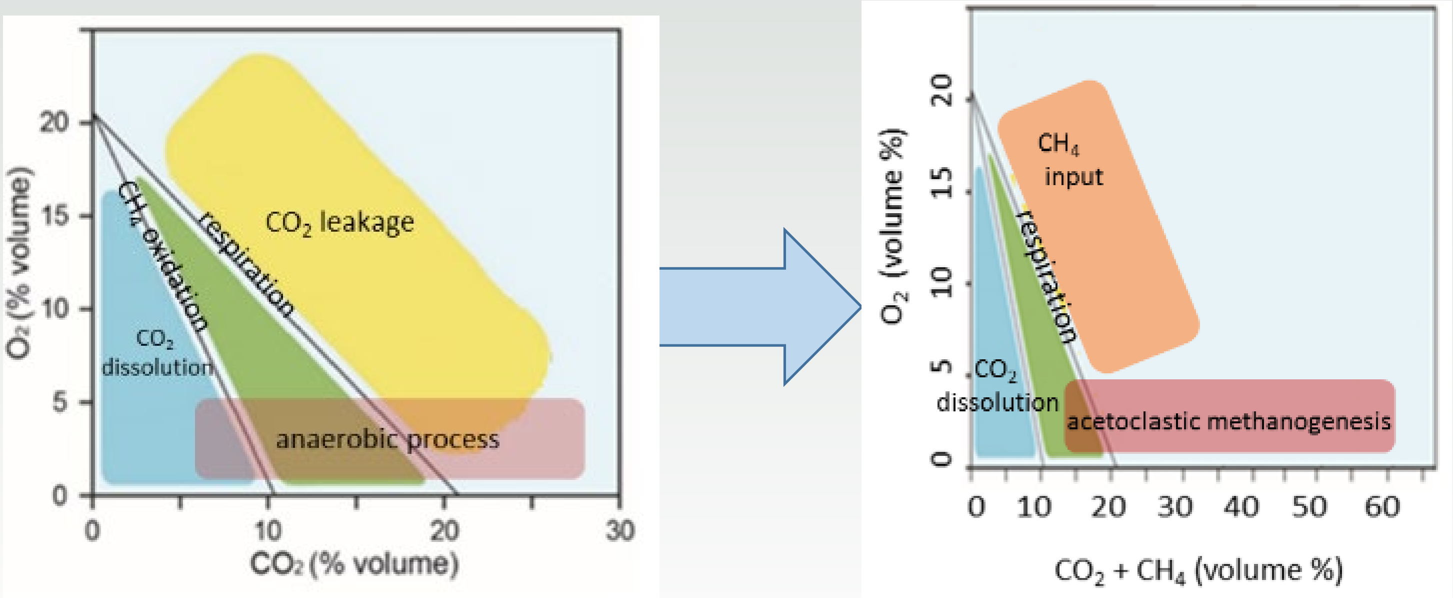
Updated Process-Based Matrix

- No methane in soil gas at Glenhaven site
- Mined data from literature + numerical modelling
- Anaerobic processes
- Acetoclastic methanogenesis : $CH_3COOH \rightarrow CH_4 + CO_2$

When significant methane is present or when anaerobic process is indicated



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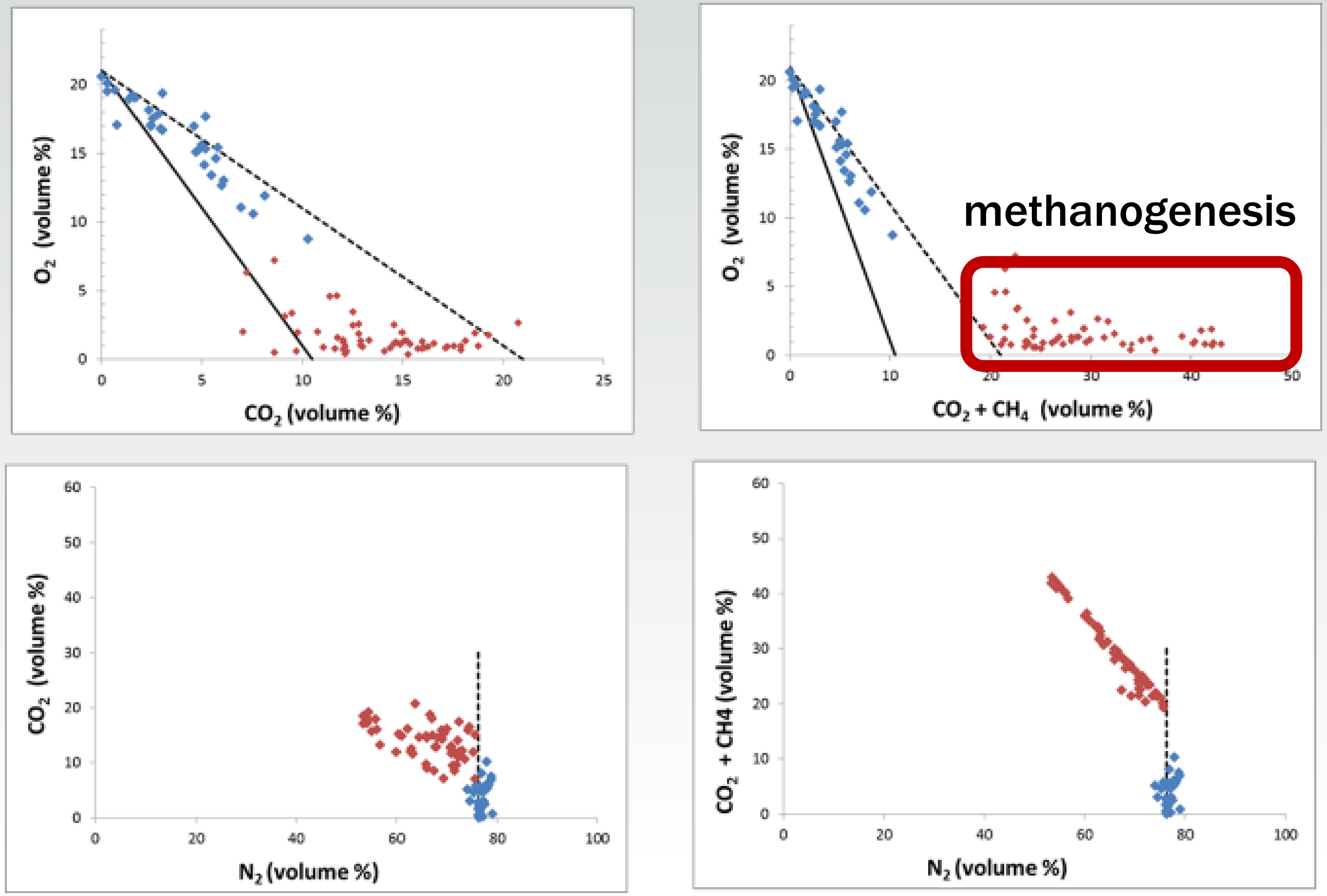
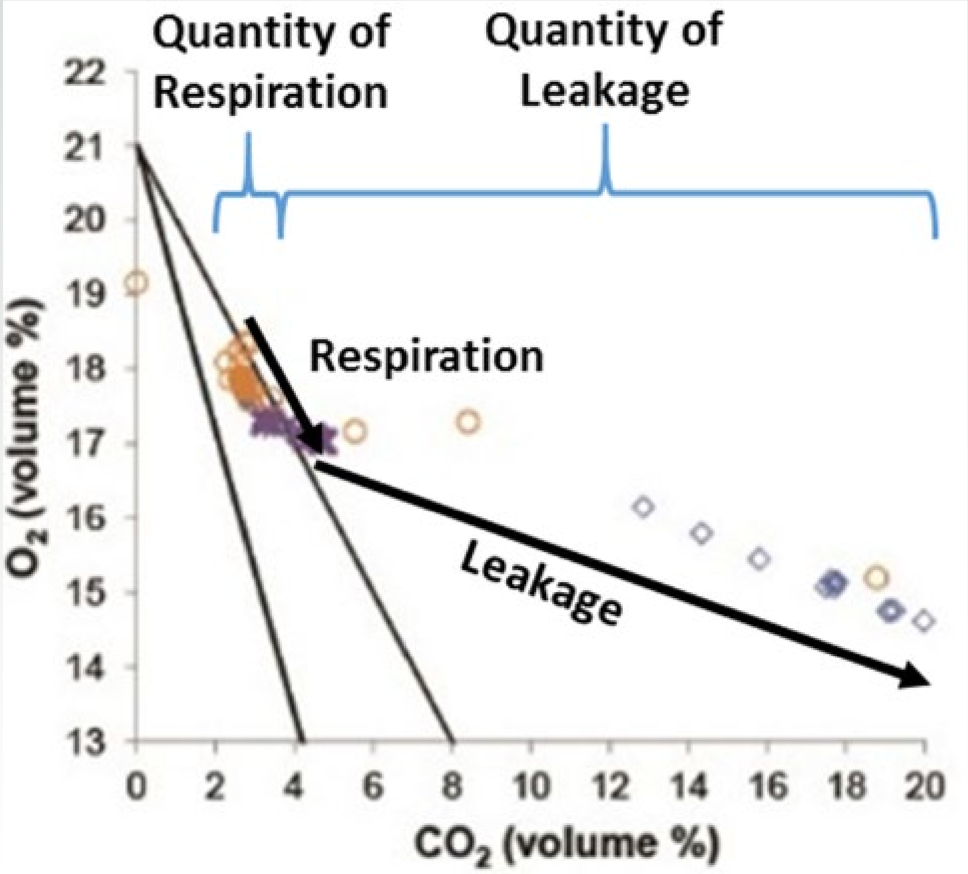
Process-Based Matrix Conclusions

- It is important to accurately measure CH_4
- Low O_2 environments signal natural processes of methanogenesis
- Including a second set of PB ratios with CO_2+CH_4 in the place of CO_2 will help distinguish and correctly attribute unexpected signals



Deliverable 2 : Integrating PB with Quantification - Theoretical approach



EPA Flux chamber method

$$EF_i = \frac{(C_i)(Q)}{A}$$

EF_i = emission rate of species i in ug/m^2min

C_i = measured concertation of species i in vol% converted to ug/m^3

Q = sweep air flow rate in m^3/min

A = exposed surface area in m^2

Eklund, B. 1992. Practical Guidance for Flux Chamber Measurements of Fugitive Volatile Organic Emission Rates. *J. Air Waste Mange Assoc* 42:1583-1591.

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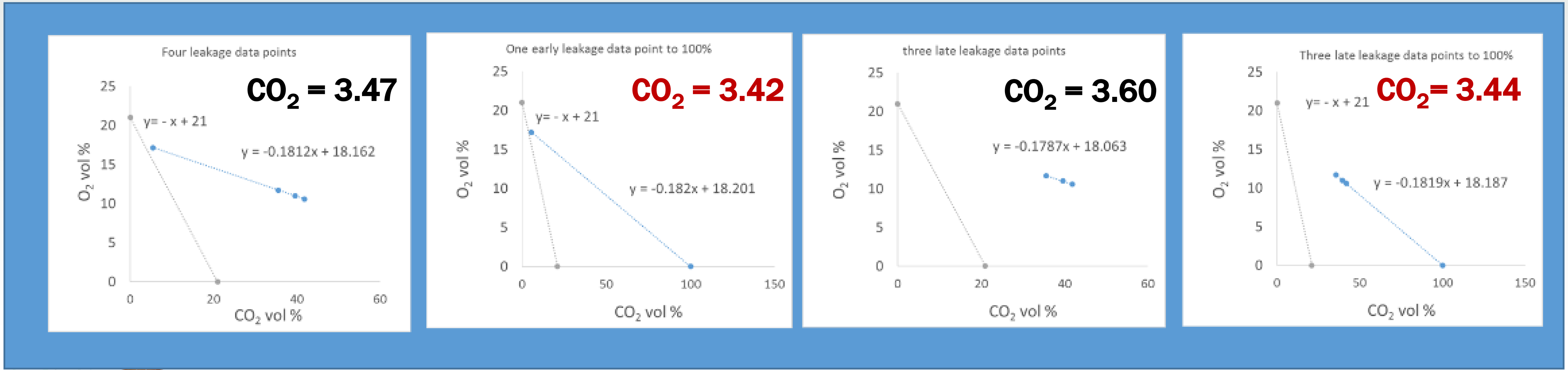
Deliverable 2 : Integrating PB with Quantification - Theoretical approach

- Assuming 100% CO_2 is being approached
- Regressions of trends calculated from various data point configurations all give accurate results for real background CO_2 of 3.43%
- Suggests assumption is valid and leakage could be separated accurately from background with minimal information.



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Quantification Conclusions

- Process-based methods shows promise for integration with flux
- Assumption that leakage trends towards 100% CO_2 appears valid
- At the ZERT site, one early or one late leakage data point combined with 100% leakage gave background CO_2 concentration within 0.01% absolute error
- Analysis of field test results are ongoing

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Sensor Testing

Sensor Type	Range	Accuracy	Response Time	Environmental Limits	Technology	Manufacturer
CO_2						
GMP 251	0 to 20%	±0.2 %	< 1 min	-40°C to +60°C 0 to 100% RH	NDIR	Vaisala
GMP 343	0 to 2%	± 3 ppm	40 secs	-40°C to +60°C 0 to 100% RH	NDIR	Vaisala
O_2						
SO 210	0% to 100%	±0.2%	14 secs	-40 to 60 C; 0 to 100% RH	Electro-chemical	Apogee
CH_4						
MSH2-LP/HC/NC	0 to 100%	±10% absolute	<10 secs	-20 to 50°C 0 to 95% RH	NDIR	Dynament

Romanak, Womack, Bomse,

- Sensors installed by CTSCo
- Maintained by ALS Geochemistry
- 3 years of process-based data collection
- Technical and economic assessment of sensing systems

Nick Hudson, Rob Heath, Paul Jensen,

Un-useable Data

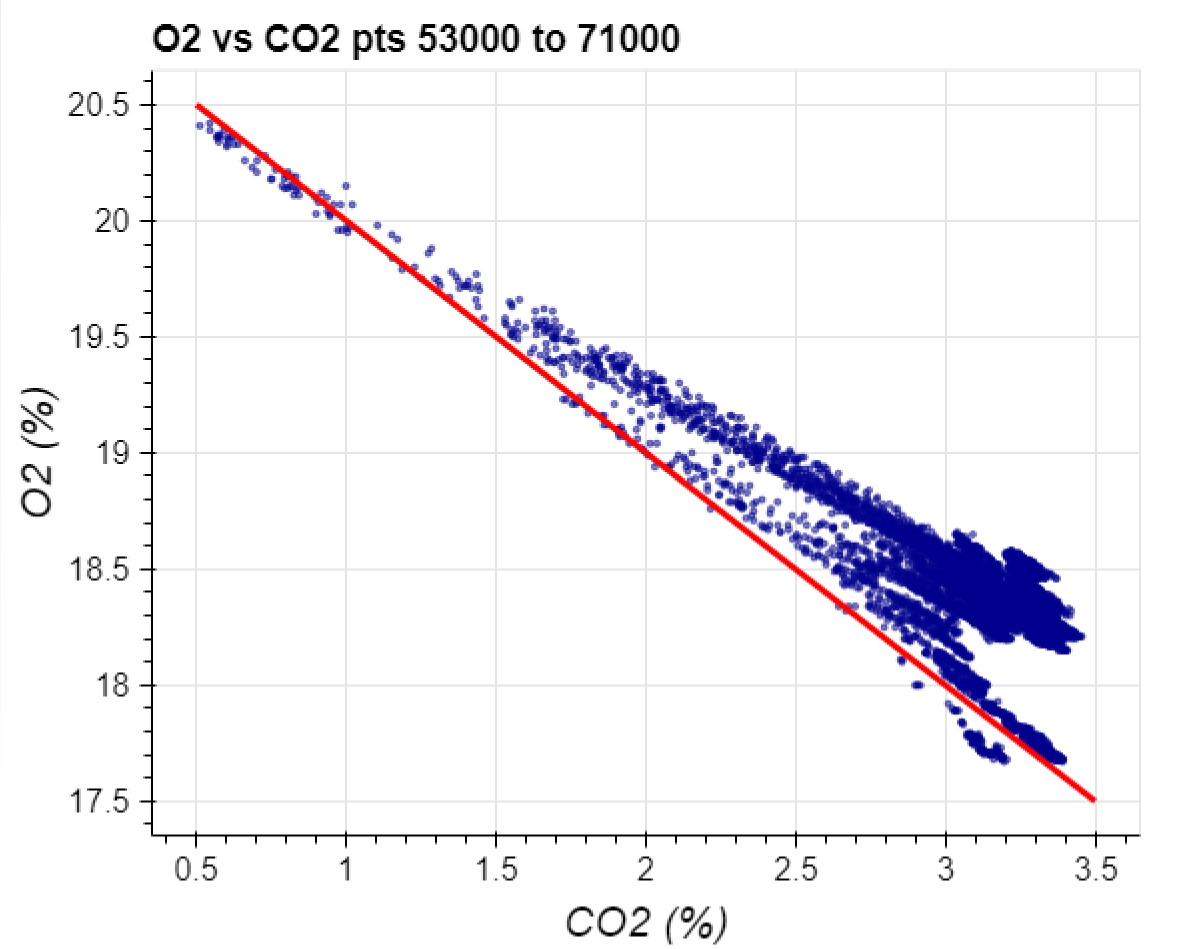
Un-useable data defined as error.
0.7 % error is acceptable

site /bore	Total Entries	CO2 # of NANs	CO2 % NANs	O2 # of NANs	O2 % NANs	O2 # of values out of range	O2 % unuseable with NANs and out of range	propagated error CO2 +O2
2SV1	126,359	5,309	4.20	75	0.06	8	0.07	4.20
2SV5	126,359	5,409	4.28	1664	1.32	3788	4.31	6.08
3SV1	140,508	25,537	18.17	1814	1.29	9207	7.84	19.80
3SV5	140,508	25,491	18.14	146	0.10	16807	12.07	21.79
4SV1	153,484	14,575	9.50	557	0.36	9313	6.43	11.47
4SV5	153,484	4,746	3.09	220	0.14	3357	2.33	3.87
5SV1	122,346	7,702	6.30	204	0.17	16265	13.46	14.86
5SV5	122,346	41,568	33.98	34881	28.51	4015	31.79	46.53

- The percentage of data that are useable is variable between sensors and among locations
- Because both sensors are required to function at the same time for PB analysis, the propagated "error" increases the number of un-useable results

False positives

- The percentage of data that are useable (95 to 40%) is variable between sensors and among locations
- Because both sensors are required to function at the same time for PB analysis, the propagated "error" increases the number of un-useable results
- Much of the data represent false positives for leakage
- CO_2 sensor looses accuracy at high concentrations and O_2 at lower concentrations.



Paul Jensen maintains the sensors

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Potential for Raman?

- Raman spectra show simultaneous detection of all four gases.
- Raman shows good linear response to changes in N_2 and O_2 at constant pressures

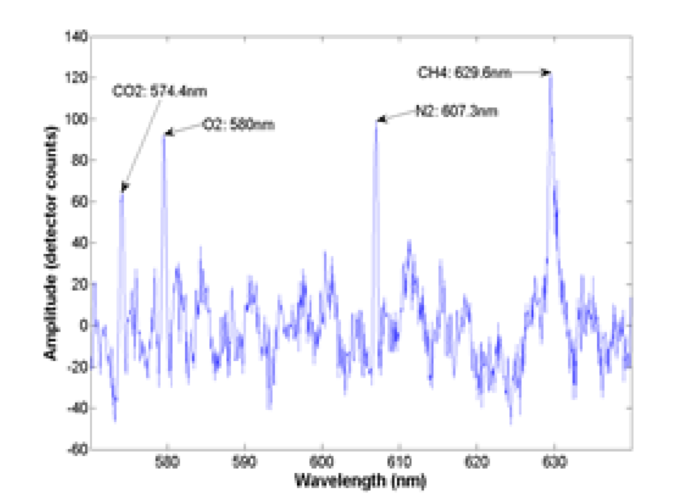

Figure 2 - HC-PCF Raman spectrum of a four-component mixture demonstrating simultaneous detection of CO_2, O_2, N_2 and CH_4 using only 1 second of signal averaging.

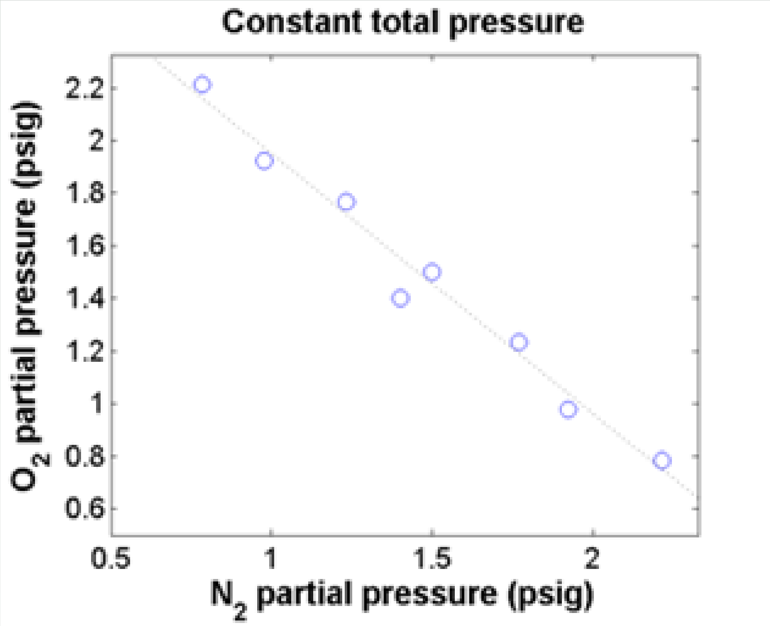

Figure 2 - ERGS linear response to changing proportions of N_2 and O_2 at constant head pressure.

Table II - Raman wavelengths and cross sections			
Compound	Raman shift (cm^{-1})	Detection Wavelength (nm)	Cross section (N_2 = 1)
Nitrogen	2330.7	607.3	1.0
Oxygen	1554.7	580.0	1.3
Carbon dioxide	1285.5	571.1	0.9
	1388.3	574.4	1.4
Methane	2914.0	629.6	6.0

David Bomse,
Mesa Photonics

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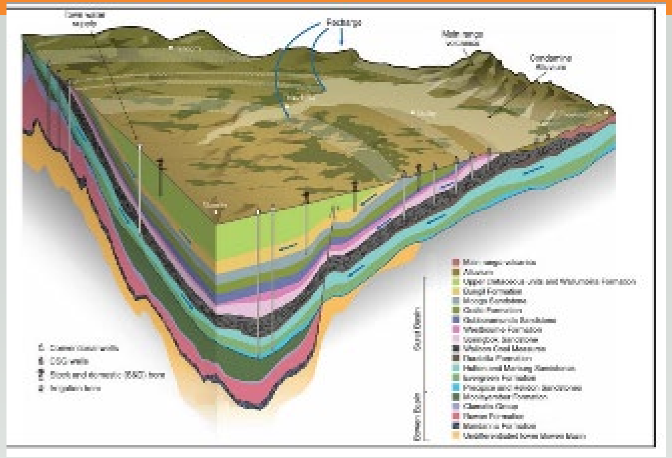
Conclusions Sensor Data

- Much of the data are unusable with a loss of accuracy over certain ranges
- Artifacts result in data slopes that give the potential for false positives.
- Effort intensive- Need to calibrate multiple sensors often
- Cost of ownership – low up front high on the back end. Sensor fits budget but then you have to maintain it.
- Recommendations for Raman development

Characterization Results

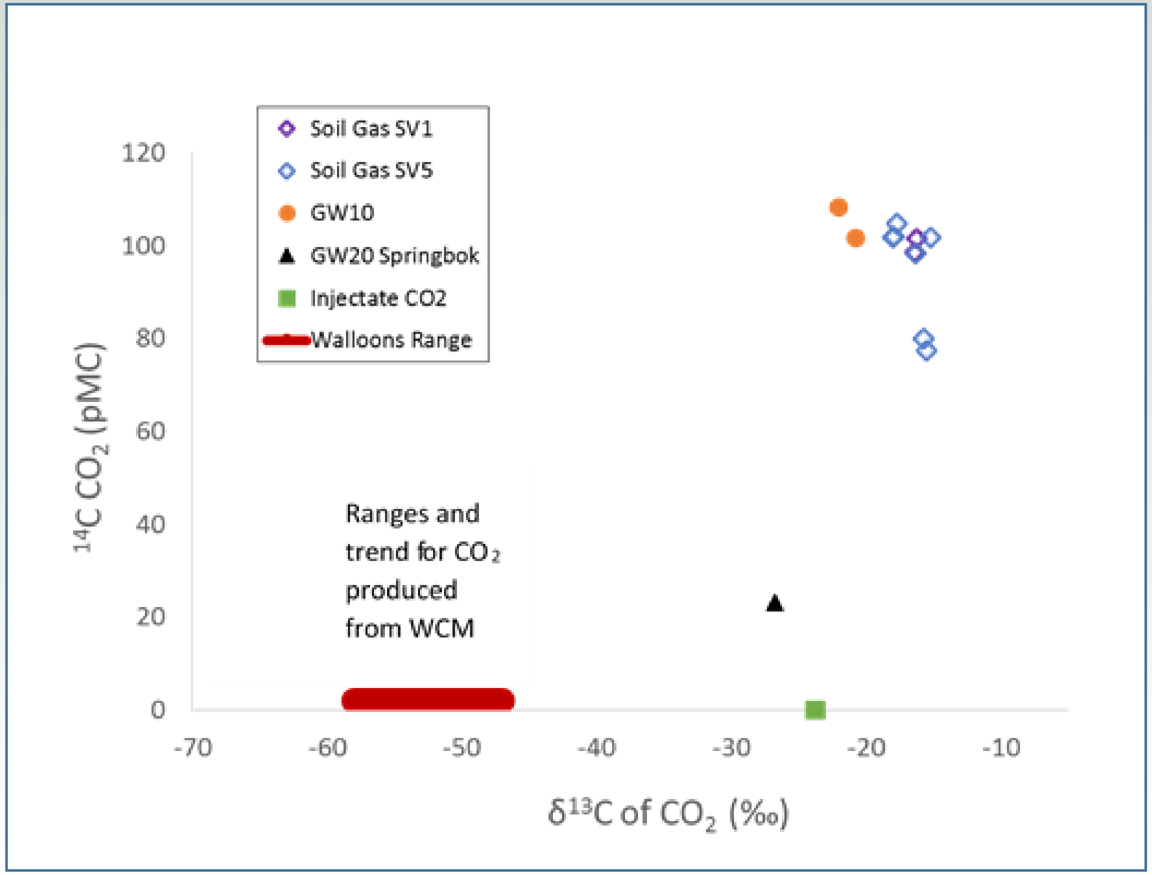
- Focus on ^{14}C versus $\delta^{13}C$ of CO_2
- Which aquifers have enough gas to impact a signal?
- Assess the CO_2 formed by CH_4 oxidation
- Look for isotopic overlap



	$\delta^{13}CO_2$		$\delta^{18}CO_2$		$^{14}CO_2$		$\delta^{13}C_1$		δDC_1		$^{14}C_1$	
	max	min	max	min	max	min	max	min	max	min	max	min
Site Soil gas	-10.9	-18.1	7.0	5.5	104.7	77.3	none	none	none	none	none	none
GW-10 (Alluvium)	-20.9	-23.4	6.2	5.4	108.3	101.7	-62.6	-77.9	-219.4	-347.1	23.0	13.8
GW-20 (Westbourne Formation)	-23.2	-29.4	6.4	5.8	23.1	13.8	-61.4	-75.3	-161.2	-223.3	13.6	2.6
Walloon Coal Measures (literature values)	7.7	-2.5	no data	no data	near 0		-45.3	-58.0	-202.0	-238.0	near 0	
Pecos Bore (Hutton Formation)	-6.8	-8.5	no data	no data	too low CO2 %		-51.1	-51.1	-211.2	-213.1	0.0	0.0
Town Bore (Precipice Sandstone)	-17.7	-17.8	4.3	4.2	too low CO2 %		-47.6	-47.8	-219.0	-219.0	10.4	1.3
Flue gas CO2	-23.8	-23.84	-6.90	-6.90	near 0		none	none	none	none	none	none

Potential for ^{14}C versus $\delta^{13}C$ of CO_2 to be useful at Glenhaven

- Gas from CSG will not be confused with CO_2 injectate.
- Influx from the Springbok Formation may be mistaken for a leakage signal
- Helium may be diagnostic



Conclusions Characterization

- A new data set represents the first full pre-project characterization for a process-based attribution method.
- It is important to have an attribution plan before a project starts to avoid stakeholder doubt (e.g. Kerr leakage claim at Weyburn).
- Assessing gas concentrations, aquifer permeability and interconnectivity can be used to simplify attribution by excluding certain aquifers as potential signals.
- Covariation of ^{14}C versus $\delta^{13}C$ of CO_2 shows promise for the second stage of process-based assessment.

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Questions?

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