Simple Method for Leakage Attribution and Quantification in the Near-Surface

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Attribution…

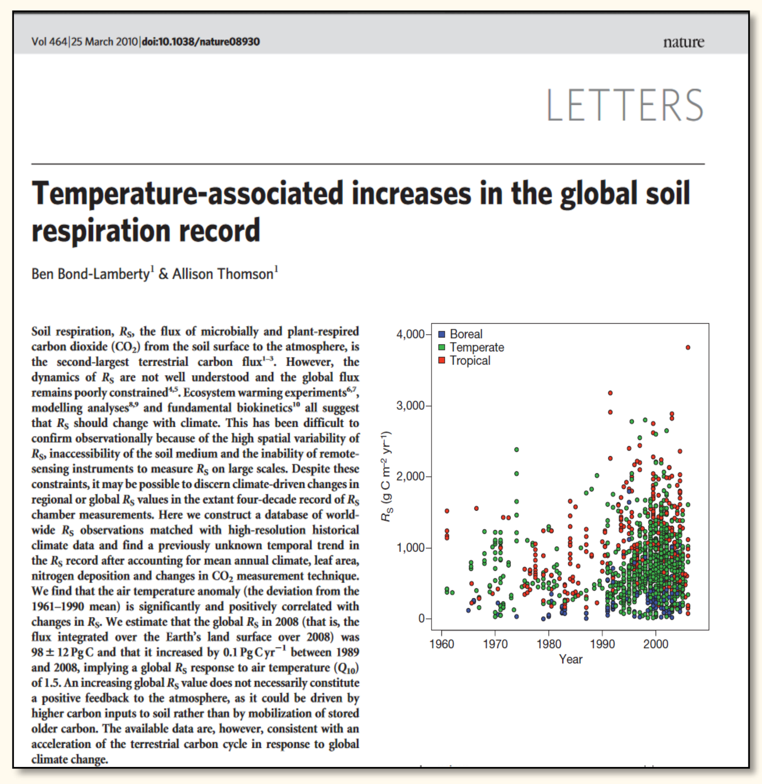
Problem: Attributing the source of a near-surface anomaly is critically important, yet current methods are not adequate and put public support of CCS and projects at risk.

Current Methods: Measure natural "background" or "baseline" CO_2 concentrations over 1-3 years to define the range of seasonal CO_2 variation. Anything different during the storage project signals a release.

Problem: Baseline is changing as a result of climate change! Baseline conditions measured at the beginning of a project will not represent baseline conditions throughout the lifetime of the project.

Solution: We need simple, accurate, stakeholder-friendly "process-based" methods.

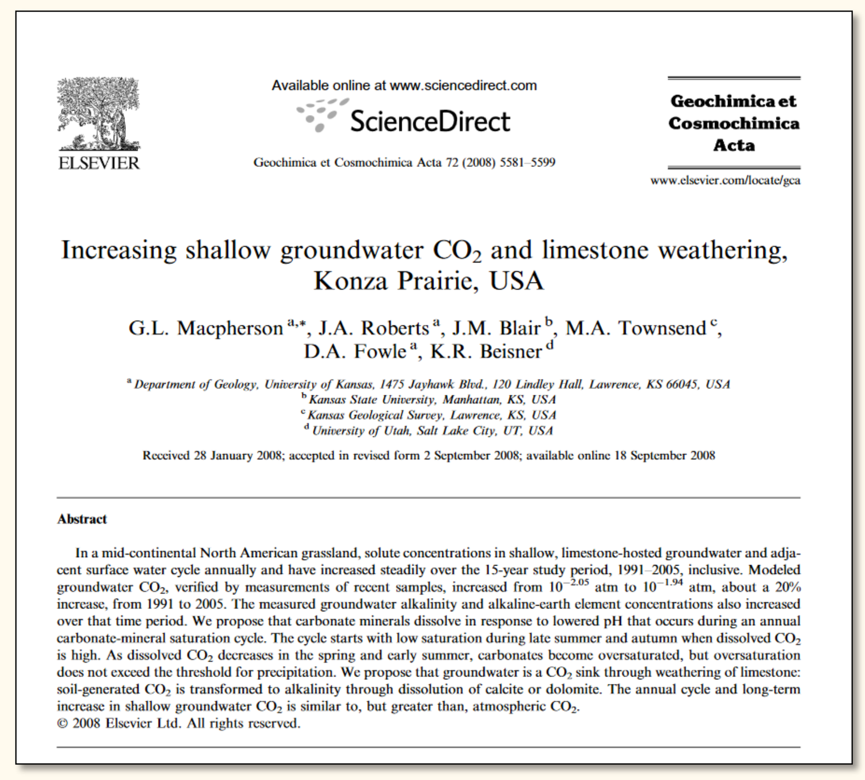
Global baselines are shifting!



LETTERS

Temperature-associated increases in the global soil respiration record

Ben Bond-Lamberty & Allison Thomson



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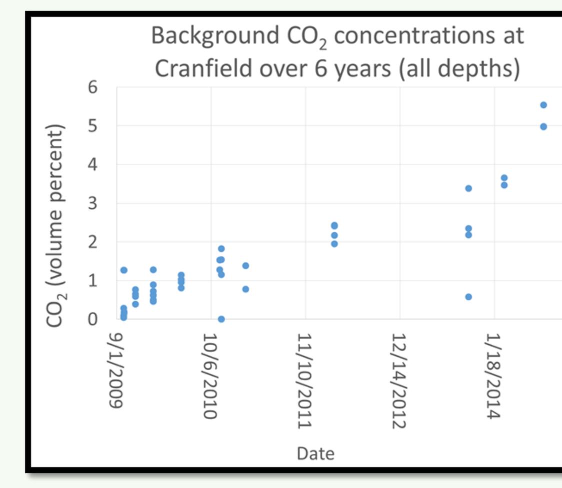
Geochimica et Cosmochimica Acta

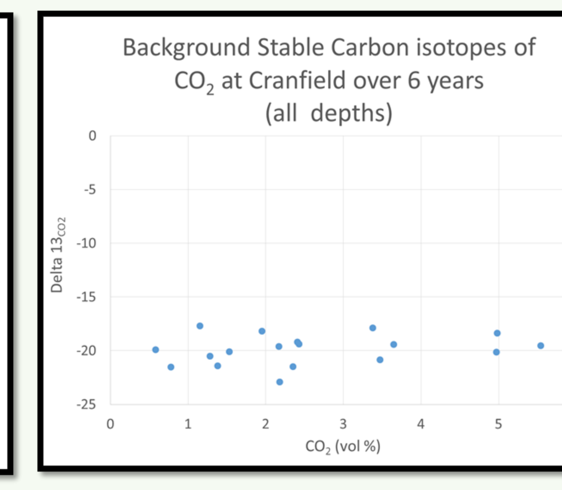
Increasing shallow groundwater CO_2 and limestone weathering, Konza Prairie, USA

G.L. Macpherson, J.A. Roberts, J.M. Blair, M.A. Townsend, D.A. Fowle, K.R. Beisner

CO_2 in soils and groundwater is increasing as a function of climate change, indicating that baselines do not exist as we have defined them!

… and at the Cranfield Site



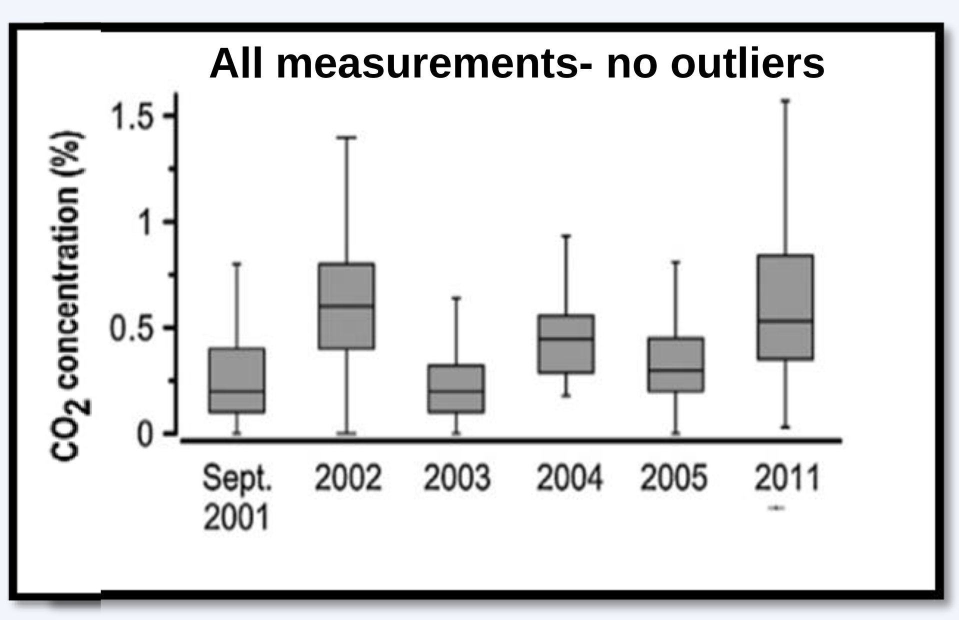


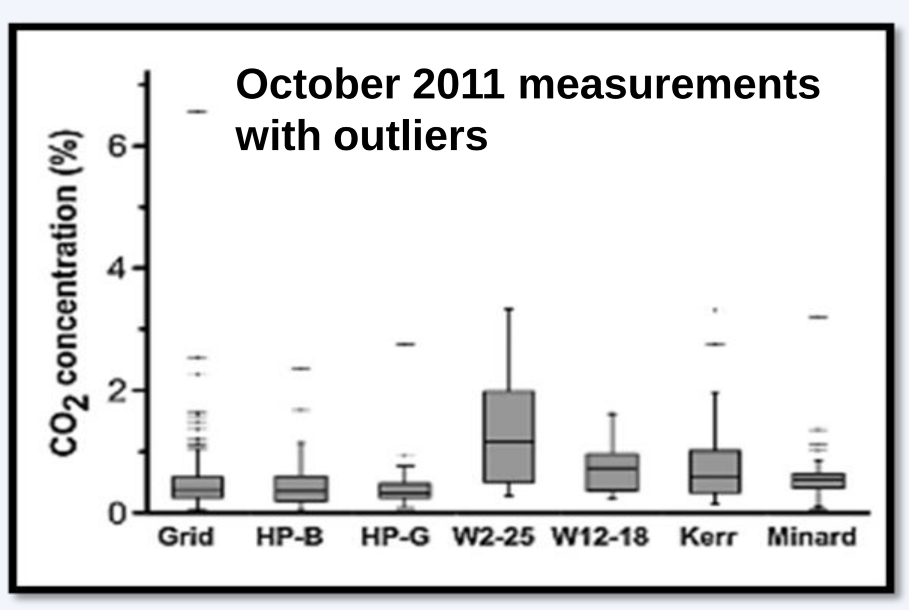
Six years of background monitoring at Cranfield shows increasing CO_2 concentrations yet no change in carbon isotopes (injectate = -5 per mil) suggesting that increased respiration is causing increased CO_2.

The risk of false positives is higher than the risk of actual leakage!

Example: IEAGHG Weyburn-Midale Monitoring and Storage Project

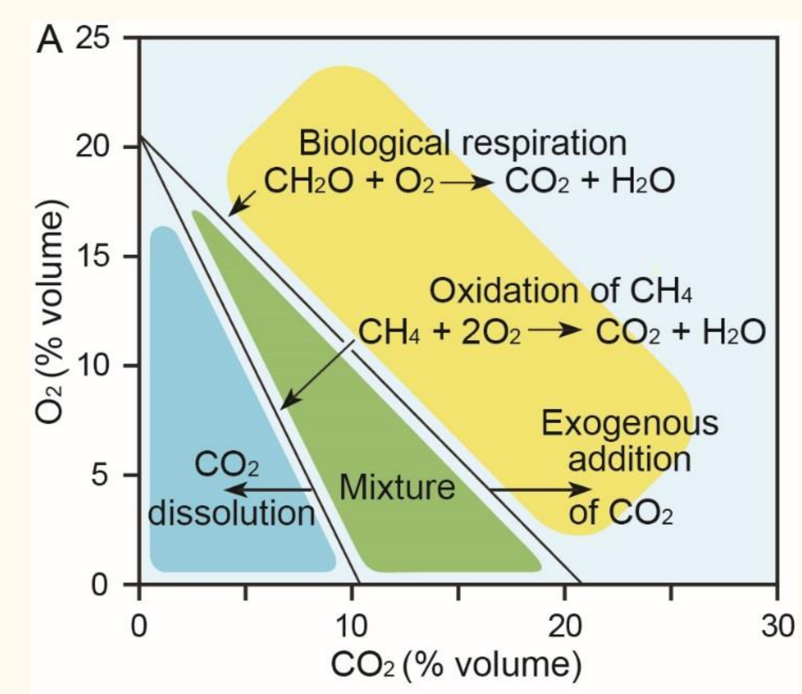
Statistical distribution of soil gas measurements at Weyburn (Beaubien et al., 2013).

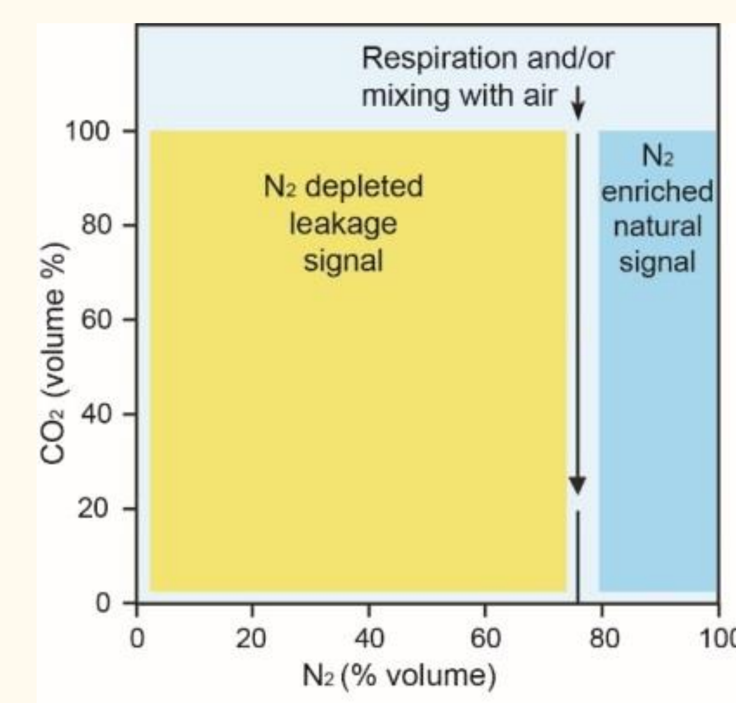




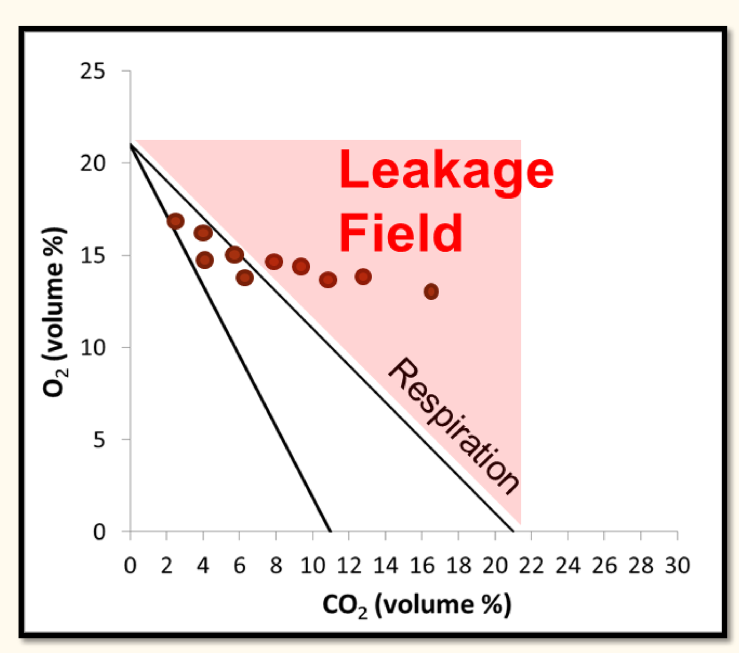
(Left) What would have happened at Weyburn in 2002, 2004, or 2011 if baseline was only measured in 2001, 2003 or 2005? (Right) If the boxes are used for assessment, the background site (Minard) has less CO_2 than the Kerr Farm, W12-18, and W2-25. If outliers are considered, the background site has less CO_2 than the grid. Such assessments would have led to false leakage claims at the Weyburn field using the current thinking on leakage attribution.

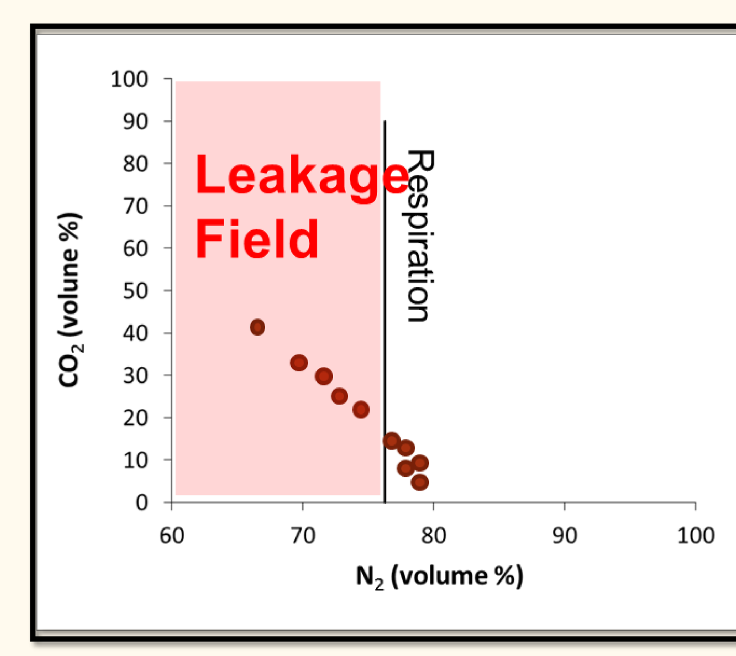
Ratios Provide Graphical, Instant, Accurate, Stakeholder-Friendly Answers!





Respiration is the main cause of environmental variability. This process can be represented by one simple line on a graph using process-based (PB) ratios (Romanak et al., 2012). Leakage will simply fall to the right of the respiration trend.





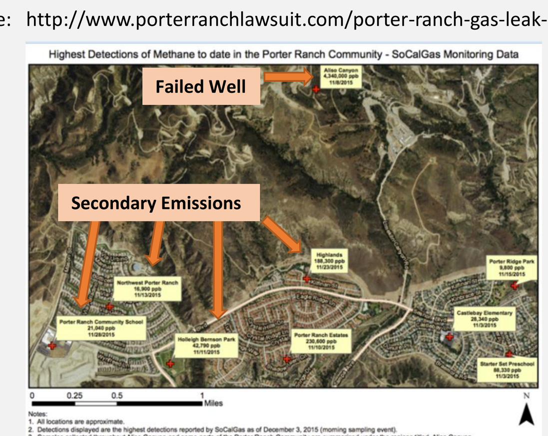
Because the method is simple and has a graphical interface, the public can understand and even implement it themselves in real-time. "Baseline" is now defined as the respiration line. Anything plotting to the right is potential leakage and can be further assessed. In this way, the threshold for action is clear, universal, and simply-defined with no ambiguity or complexity to confuse stakeholders.

Quantification…

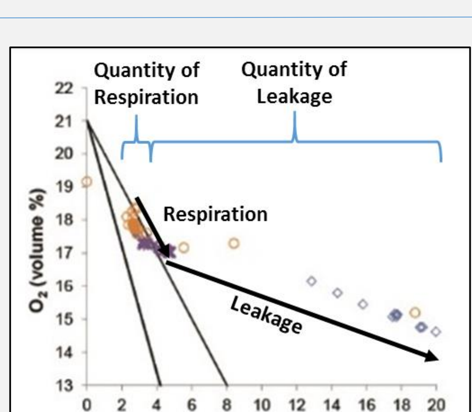
- Will be required by global protocols and regulations when surface gas emissions are attributed to leakage from a CO_2 storage formation (e.g. Dixon and Romanak, 2015).
- Is defined as the flux across ground surface into the atmosphere.
- Will likely be undertaken in discrete areas within the larger area of review where leakage is occurring.
- Will require delineating the areal extent of leakage (apart from natural signals).
- Will benefit from continuous monitoring capabilities to document and measure the fluctuating nature of surface gas emissions.
- Will benefit from clear confirmation of the degree to which remediation efforts are effective.
- Will benefit from the capability to understand the fate of the CO_2 within the environment (e.g. what amount, if any, will be naturally attenuated and how).

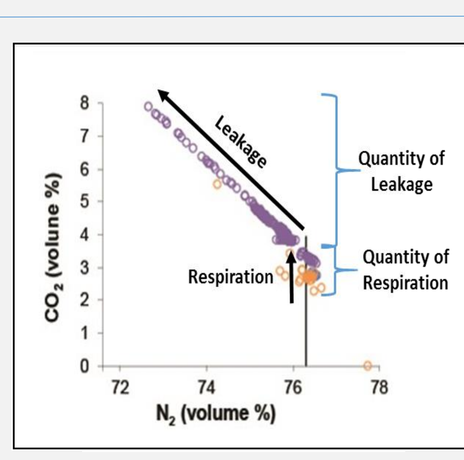
Industrial Analogue: Aliso Canyon Natural Gas Leak

Source: http://www.porterranchlawsuit.com/porter-ranch-gas-leak-map/



The well failure resulted in several areas of surface flux far from the well. How will these types of emissions be identified as leakage, quantified, and monitored for effective remediation at CO_2 storage sites?





Monitoring of simulated leakage at the ZERT site (Romanak et al., 2014) shows that a PB method can separate natural from leaked CO_2. Can this method increase the accuracy of emissions quantification and delineate areal extent of leakage?

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

EF_i = emission rate of species i in ug/m²min
C_i = measured concertation of species i in vol% converted to ug/m³
Q = sweep air flow rate in m³/min
A = exposed surface area in m²

The open flux chamber method allows measurement of all gases of interest for a PB method. Flux equations include a concentration term (Ci) suggesting that PB relationships can translate to flux measurements. PB ratios may be useful for separating natural CO_2 from leaked CO_2, delineating the spatial extent of leakage for quantification and for monitoring leakage remediation efforts. This is an area for further work.

Conclusions and Implications

- Most protocols call for the use of baseline values to determine if variability is from leakage or natural variation.
- Baselines are shifting due to climate change and will not provide accurate "attribution" of anomalies.
- Using a "baseline concentration" method will lead to many false positives and threaten public perception and projects.
- The risk of a false leakage claim due to inaccurate attribution is higher than the risk of actual leakage.
- There is a great need for accurate methods and protocols for attribution to be in place before a project begins.
- A process-based type of approach will give more accurate, immediate, and stakeholder-friendly monitoring results and may be useful for quantification and remediation monitoring.

References:

- Beaubien et al., 2013, *International Journal of Greenhouse Gas Control*, 16, Supplement 1, pp. S236–S262.
- Dixon, T., and Romanak, K. D., 2015, *International Journal of Greenhouse Gas Control*, *41*, 29-40.
- Romanak, et al., 2012, *Geophysical Research Letters*. 60 (2), 227–239.
- Romanak et al., 2014, *International Journal of Greenhouse Gas Control*, *30*, 42-57