

Revelations in Monitoring

Why environmental monitoring
isn't just for leakage anymore

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BUREAU OF
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Trondheim Norway

Main Questions from Stakeholders

- Is it safe?
- Will it leak?
- What happens if it leaks?



Geologic CO₂ Storage - Safe By Design

1. Site Characterization – Permitting requires high level of assurance
2. Risk Assessment- Modeling identifies potential unwanted outcomes
3. Project Design - to minimize potential risk
4. Monitoring Plan

Deep Subsurface – Verification

Behavior conforms to predictions

Shallow Subsurface - Assurance

No unwanted outcomes to environment

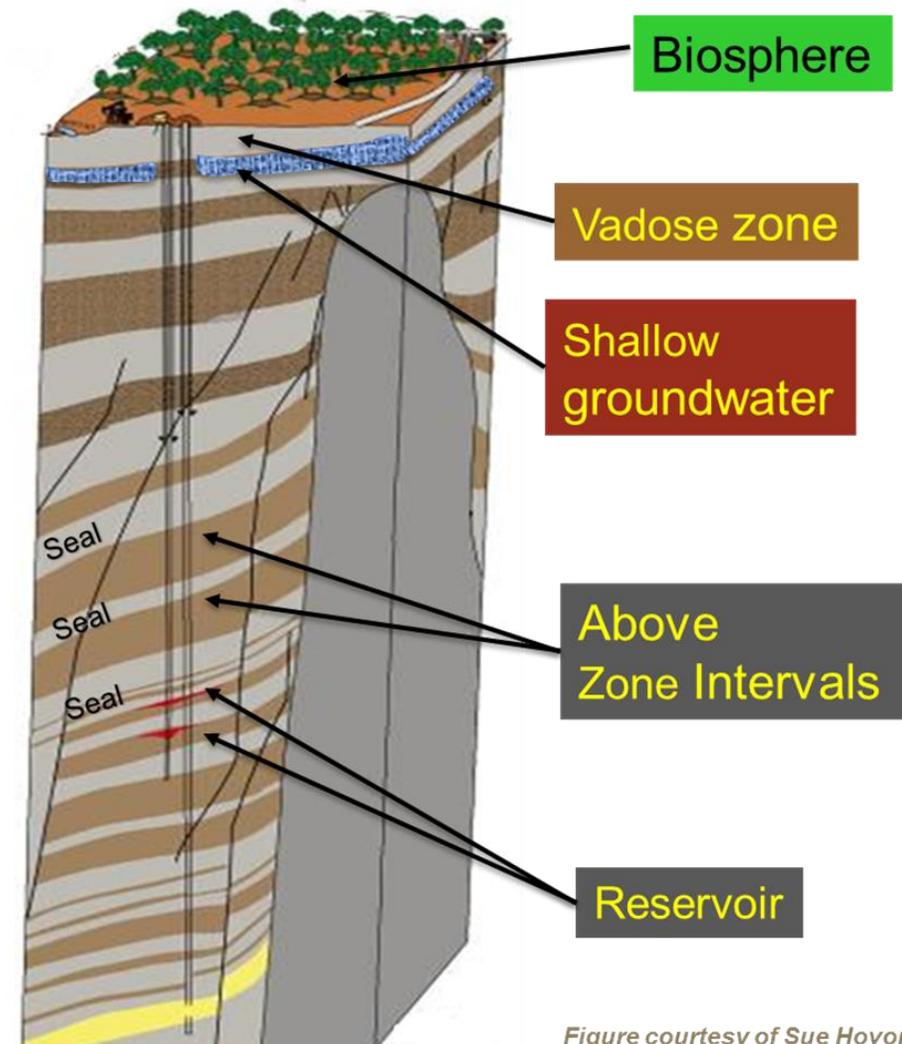
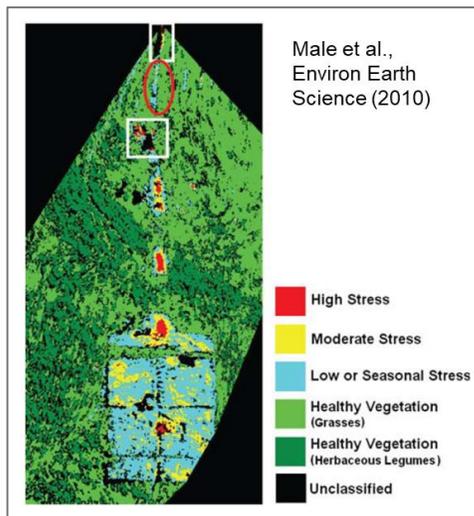


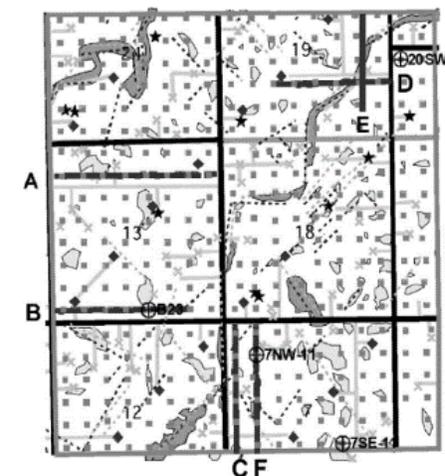
Figure courtesy of Sue Hovorka

The Lengths We Go To - Finding a Leak

- Soil gas Grids
- Remote Sensing
- Drones/AUVs
- Sonar
- Open path lasers
- Eddy covariance
- Hyperspectral for Vegetation health



(Jones et al. 2009)

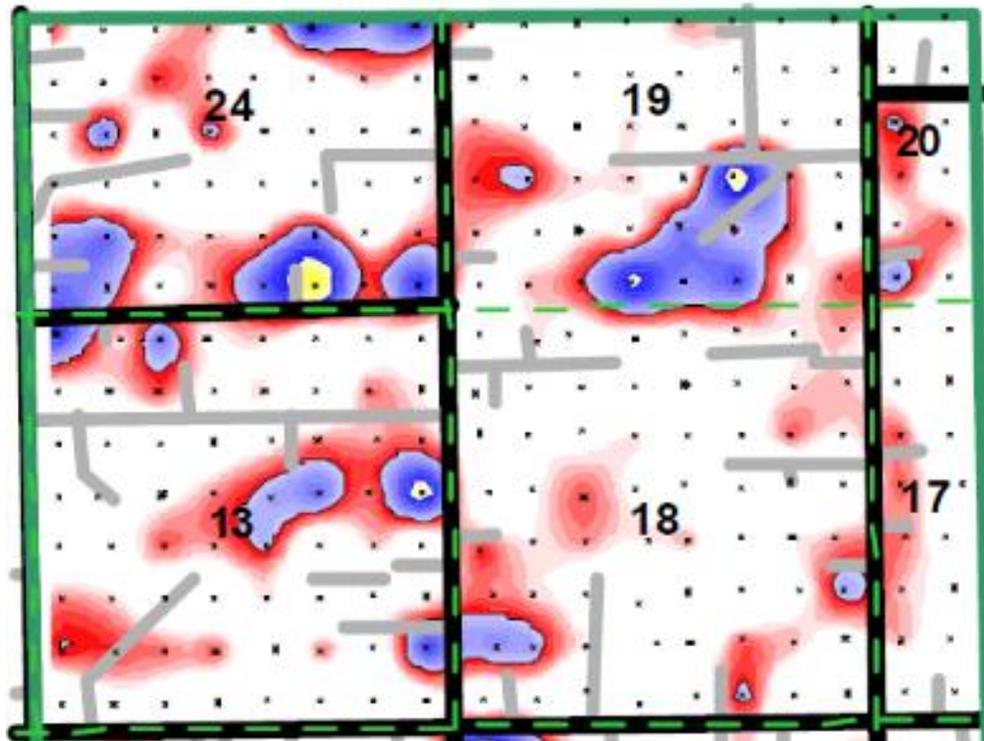


Weyburn soil-gas grid: 14 km², 200 m spacing (Riding and Rochelle, 2009).

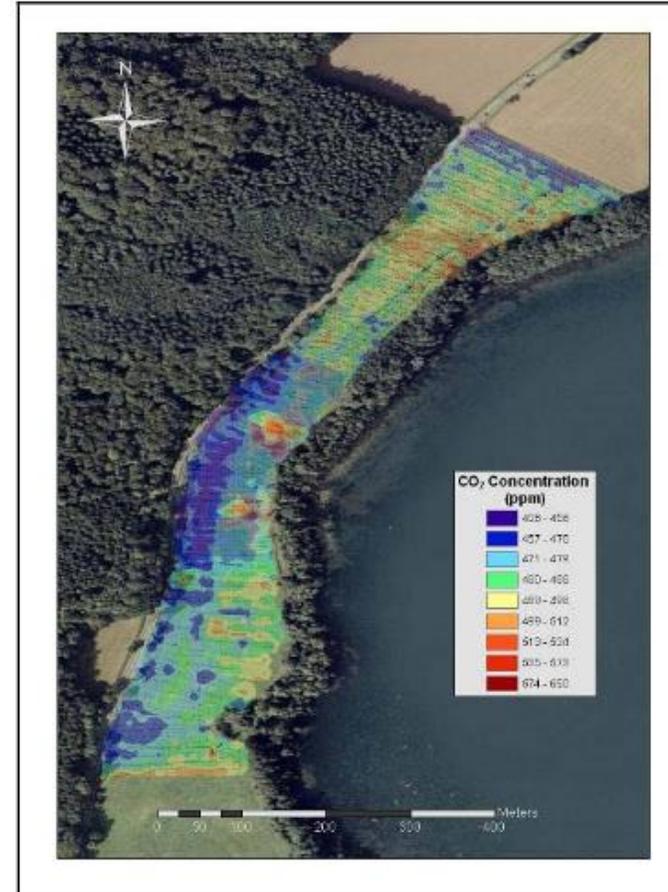


CO₂ Source Attribution

B) CO₂ flux (g/m²/d) - October 2005



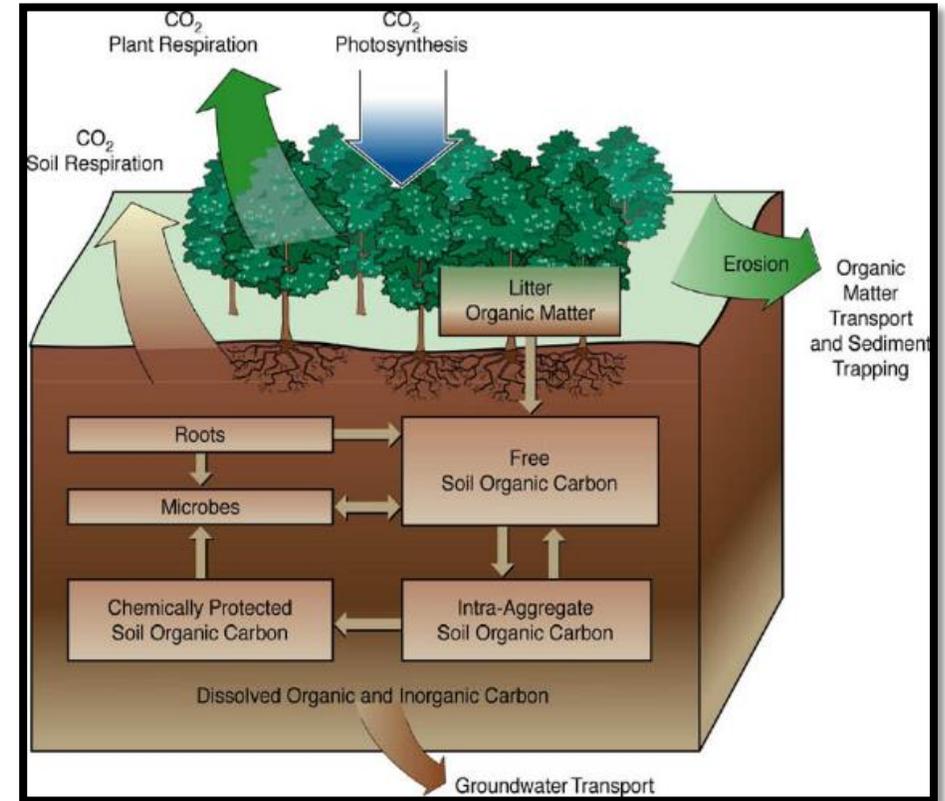
Weyburn soil-gas grid: 14 km², 200 m spacing. Jones et al., 2006, Soil Gas Monitoring at the Weyburn Unit in 2005



Walking traverses over gas vents at Latera with the ground surface measurement system (infrared analyzer) measuring CO₂ concentrations (Jones et al. 2009)

CO₂ Variability

- CO₂ is naturally everywhere
- Dominant source is biological respiration
- Dynamic over space and time (temperature, rainfall, pressure...)
- CO₂ is reactive
- Very difficult to discern leakage from natural variability.
- Difficult to determine what is anomalous



Source: DOE, 1999: Carbon Sequestration Research and Development

Determining Anomalies Using Baselines

- Measure “baseline” CO₂ for 1 year before project starts to document seasonal variability.
- Monitor CO₂ during project and compare to baseline.
- Significant increase from baseline during a project signals a  anomalous CO₂
- Did the storage project cause the anomaly?
- “Attribution” is a missing step



http://www.sustaenable.eu/?page_id=932

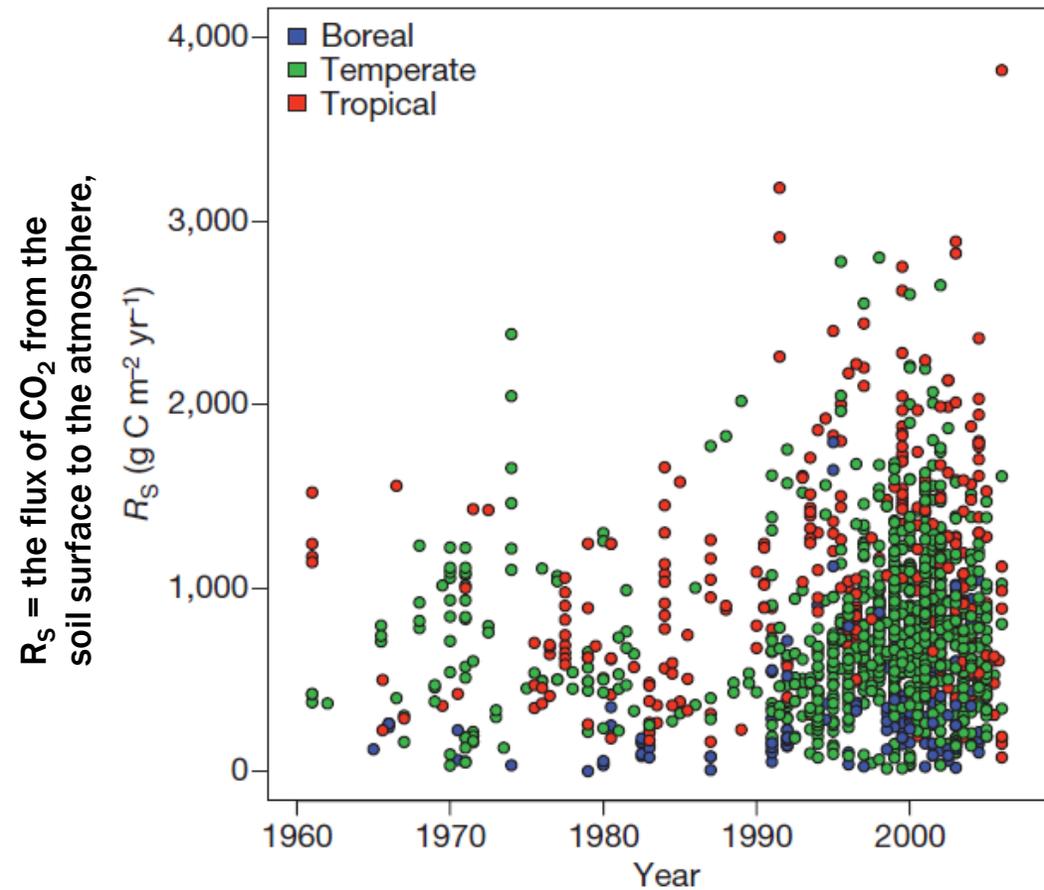
Global Regulations

Regulatory Body Monitoring Objectives:	IPCC GHG Guidelines	EU		London Convention and Protocol	OSPAR	UNFCCC Clean Development Mechanism	US EPA	
		CCS Directive	ETS Directive				UIC Class VI well regulation	GHG reporting Subpart RR
Overall Objectives	GHG accounting	Protection of the environment	GHG accounting	Protection of the marine environment	Protection of the marine environment	GHG accounting and protection of the environment	Protection of the environment (underground sources of drinking water)	GHG accounting
Baseline/ Background Measurements	✓	✓				✓	✓	✓
Storage Performance	✓	✓		Only in terms of retention	Only in terms of retention	✓	Only in terms of pressure and plume extent	
Detection of Leaks or Anomalies	✓	✓		✓	✓	✓	✓	✓
Attribution of Leaks and/or Anomalies	Mentions in the context of baseline isotopic ratios. Not included as a step					Not included as a step but accommodates a range of monitoring techniques		Mentions in the context of baseline CO ₂ concentrations. Not included as a step
Environmental Impacts		✓		✓	✓	✓	✓	
Quantification of GHG	✓		✓			✓		✓

“Baselines” in Soils are Shifting Upwards

Temperature-associated increases in the global soil respiration record

Ben Bond-Lamberty¹ & Allison Thomson¹



“Baselines” in Groundwater are Shifting Upwards



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Available online at www.sciencedirect.com



Geochimica et Cosmochimica Acta 72 (2008) 5581–5599

**Geochimica et
Cosmochimica
Acta**

www.elsevier.com/locate/gca

Increasing shallow groundwater CO₂ and limestone weathering, Konza Prairie, USA

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D.A. Fowle^a, K.R. Beisner^d

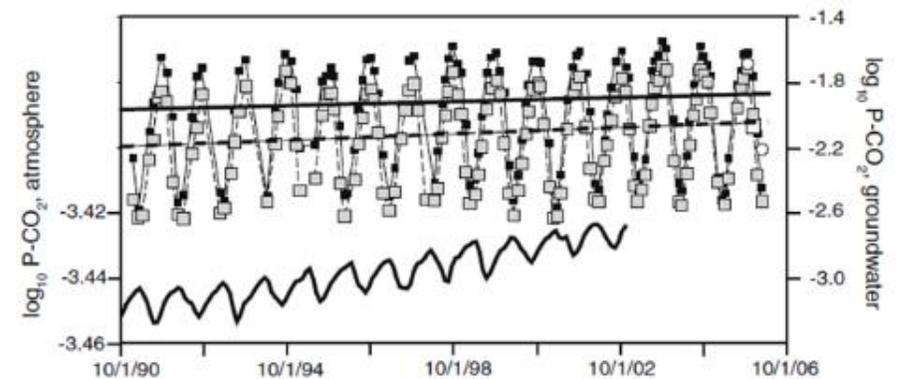
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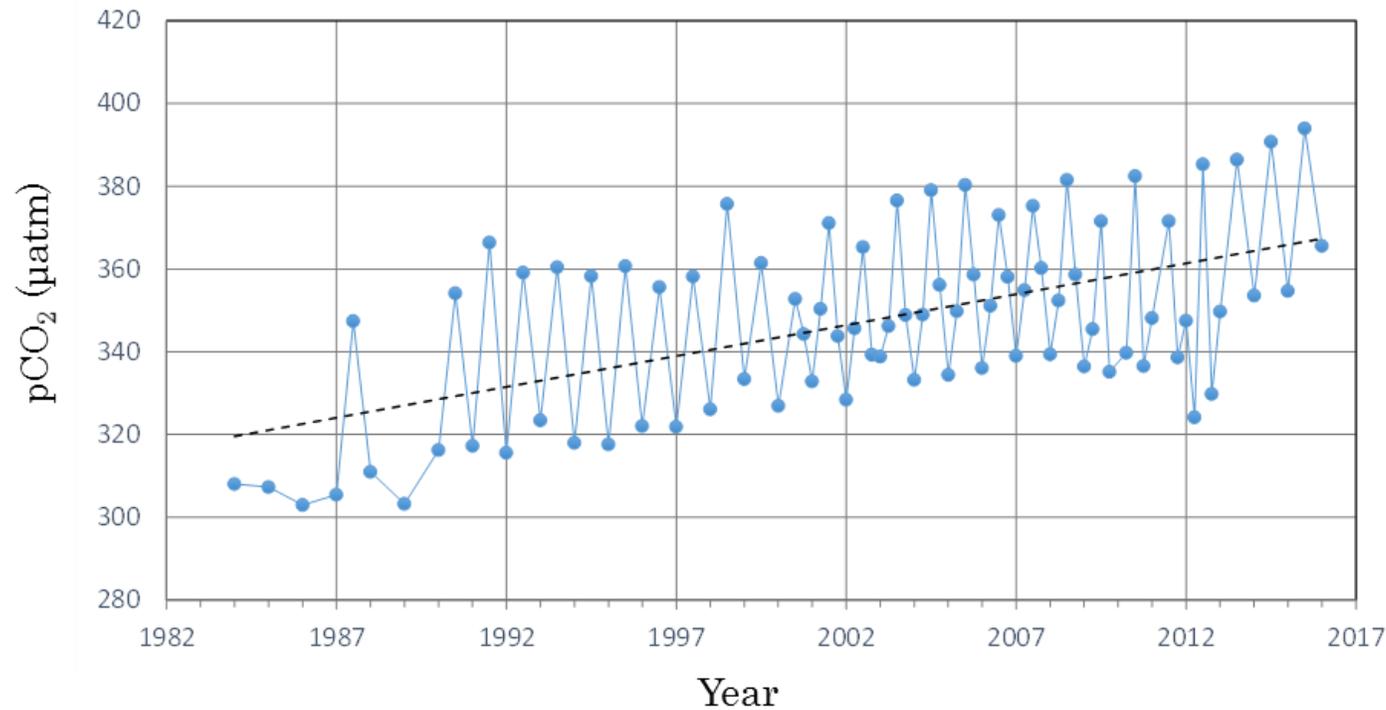
^d University of Utah, Salt Lake City, UT, USA

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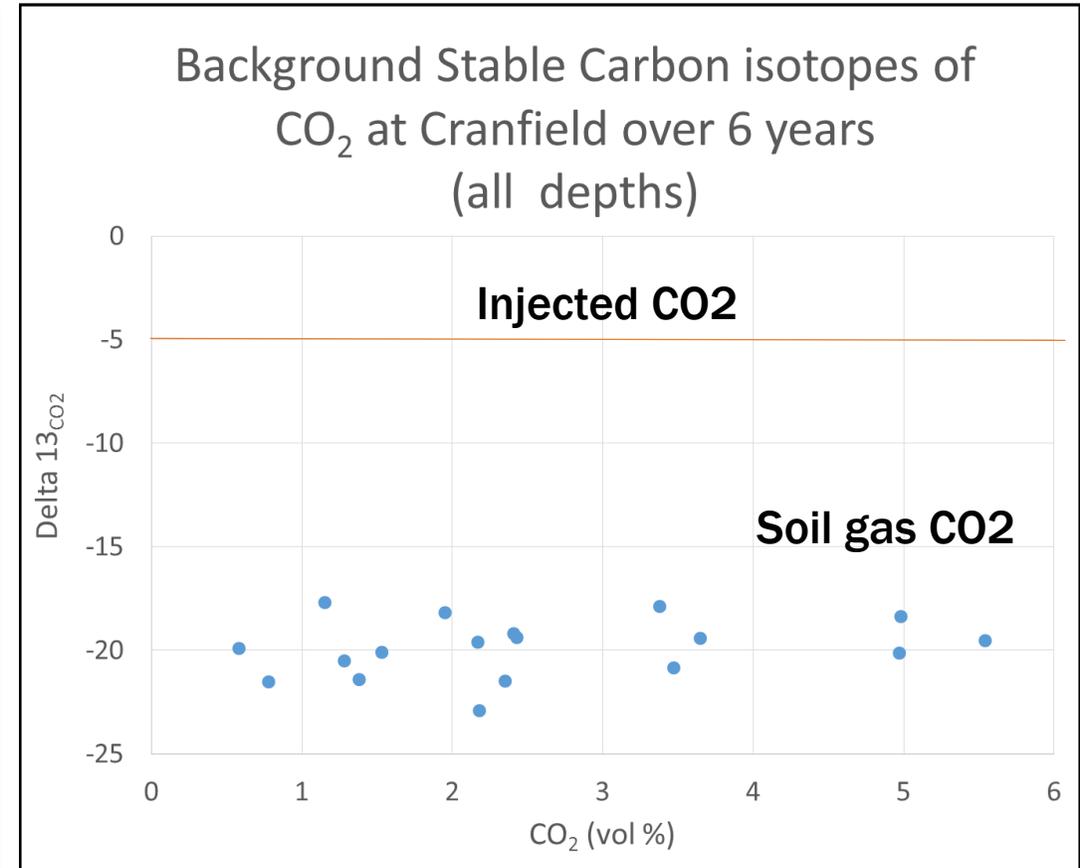
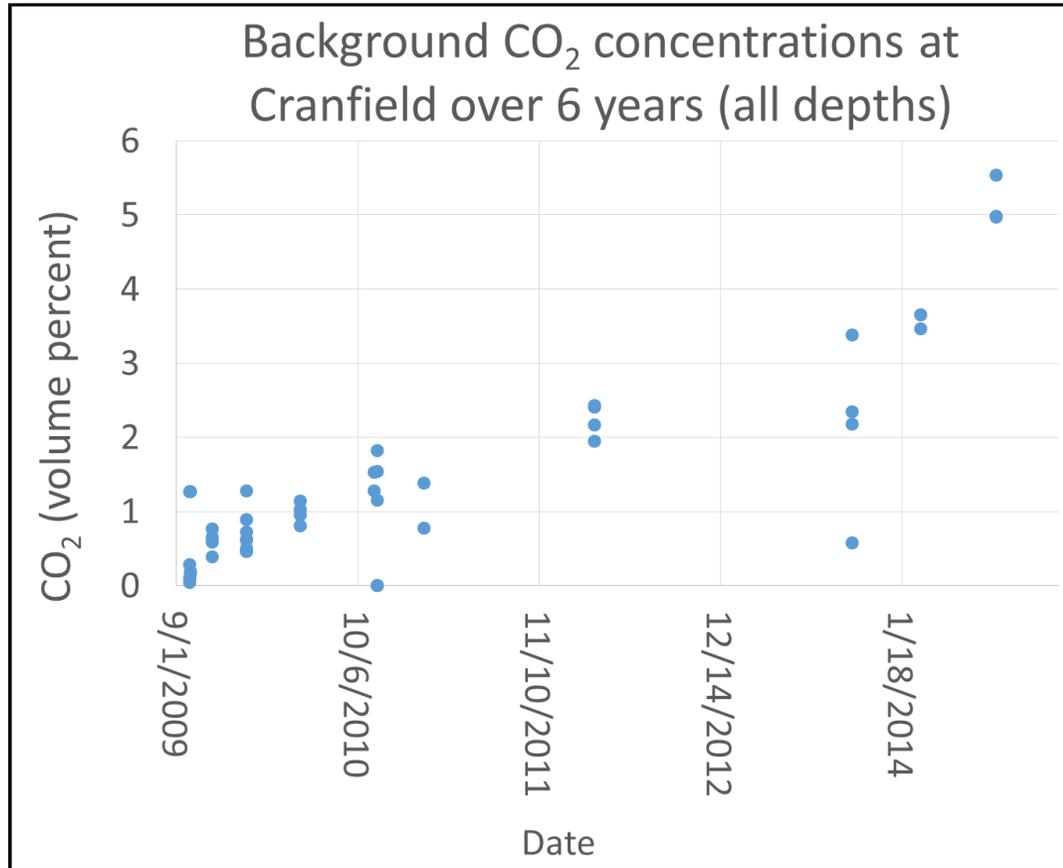
Increased dissolution of CO₂ in groundwater and associated mineral dissolution

“Baselines” in Seawater are Shifting Upwards



Time series of surface seawater CO₂ level near Japan. Source data by Japan Meteorological Agency, Courtesy of Jun Kita, RITE

Example – Soil Gas at Cranfield Project (Mississippi, USA)





Revelation #1

- Naturally produced CO₂ in the biosphere is increasing due to climate change
- Use of “concentration-based” or “baseline” methods will result in false positives for leakage
- **The risk of false positives is greater than the risk of actual leakage**
- False positives put projects at unnecessary risk

Tomakomai Project

- Tomakomai Offshore demonstration project Hokkaido Japan
- Derived leakage thresholds from 1 year of baseline data
- Injection began April 2016 with routine environmental monitoring plan
- May, 2016, operations were halted after 7,163 ton CO₂ was injected
- High CO₂ levels observed in the routine monitoring
- February 2017 operations resumed

Shifting baselines cause false positives and project shutdowns





Revelation #2

- If we actively look for “leakage” (e.g. via routine monitoring) we will find an abundance of natural anomalies
- We will need to attribute the source of these anomalies.
- Baseline methods are not effective or accurate.
- So how do we adequately assure environmental safety?

2011 Kerr Leakage Allegation

- IEAGHG Weyburn CO₂ Monitoring and Storage project, Saskatchewan Canada
- Perceived environmental change was blamed on the CO₂ storage project
- Protocols for responding to stakeholder concerns were not in place
- Unexperienced consultant wrongly attributed leakage



Negative Media Storm

THE GLOBE AND MAIL
IN PICTURES
Carbon capture leak forces Saskatchewan couple to leave farm
Published Tuesday, Jan. 11, 2011 6:12PM EST
Pair abandon Saskatchewan farm because of blowouts, dead animals and algae



1 of 10

(Troy Fleece/The Canadian Press)

Carbon injected underground is leaking: Sask. farmers



Cattle gathered in a pasture near a pumpjack in an offield outside of Weyburn, Sask. on Monday, June 8, 2008.

The Canadian Press
Published Tuesday, Jan. 11, 2011 11:37AM EST

CBCnews
Home World Canada Politics Health Arts & Entertainment Techno

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CO2 leaks worry Sask. farm

Last Updated: Tuesday, January 11, 2011 | 8:40 PM ET | Comments [164](#) | [Recommend](#)

The Canadian Press

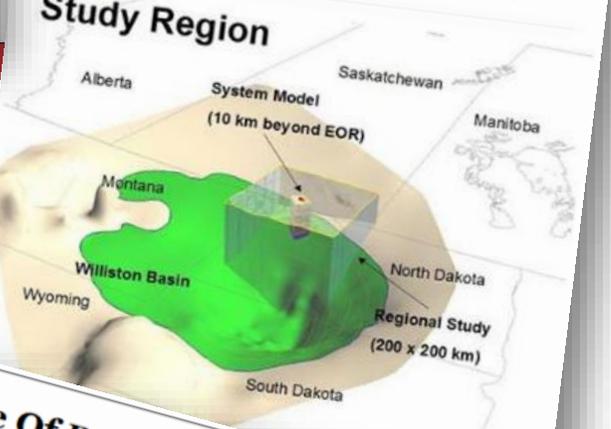
SCIENCE + TECHNOLOGY

Week in Pics: The News In Review | Bacteria: Good, Bad, and Ugly | The Week: In Animal Photos

CO2 Levels at Leaking Canadian Carbon Storage Project Could Asphyxiate You In One Place
by Matthew McDermott, New York, NY on 01.12.11
SCIENCE & TECHNOLOGY

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Study Region



Land fizzing like soda pop: farmer says CO2 injected underground is leaking
By: Bob Weber and Jennifer Graham, The Canadian Press
Posted: 01/11/2011 10:22 AM | [Comments: 9](#)

Pffft Goes Promise Of Pumping CO2 Underground

Cameron and ... above the Weyburn oilfield in Saskatchewan, have released a consultant's report that claims to link high concentrations of carbon dioxide in their soil to gas injected underground

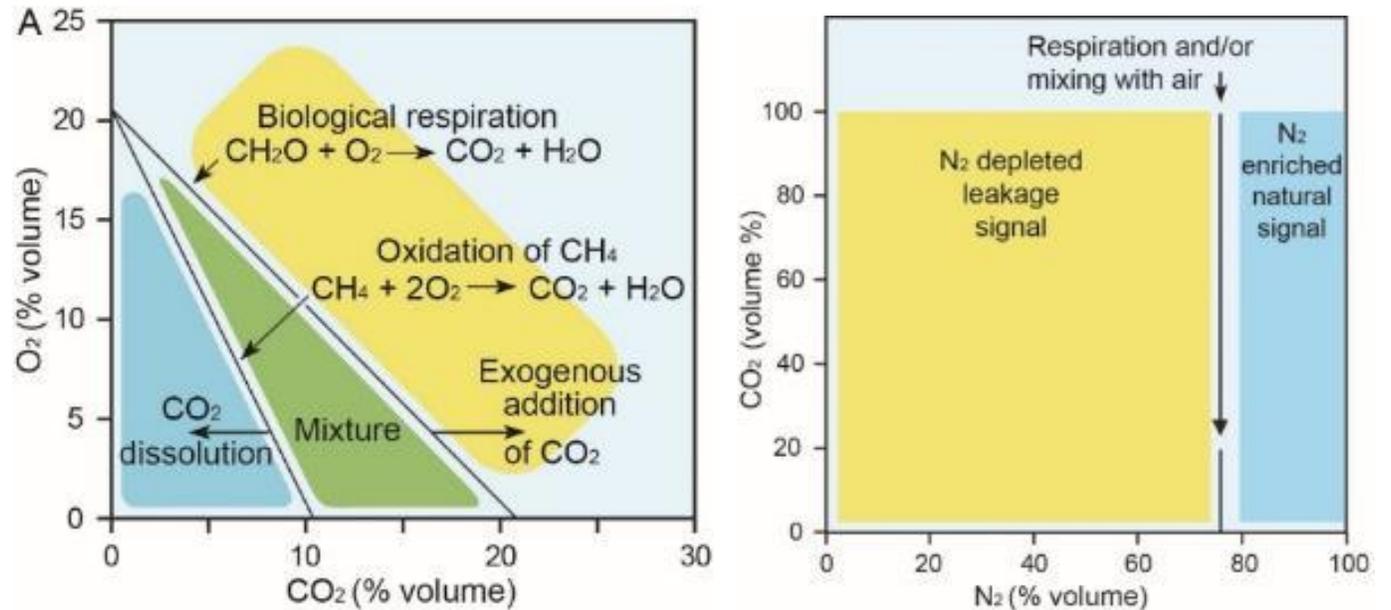
Revelation #3

- Environmental change resulting from climate change will cause stakeholders to question the storage project
- When CCS is fully deployed, responding to stakeholders concerns may be our main activity.
- Develop fast accurate stakeholder-friendly methods with clear thresholds
- Methods that are easily communicated to stakeholders are needed



Process-Based Soil Gas Ratios

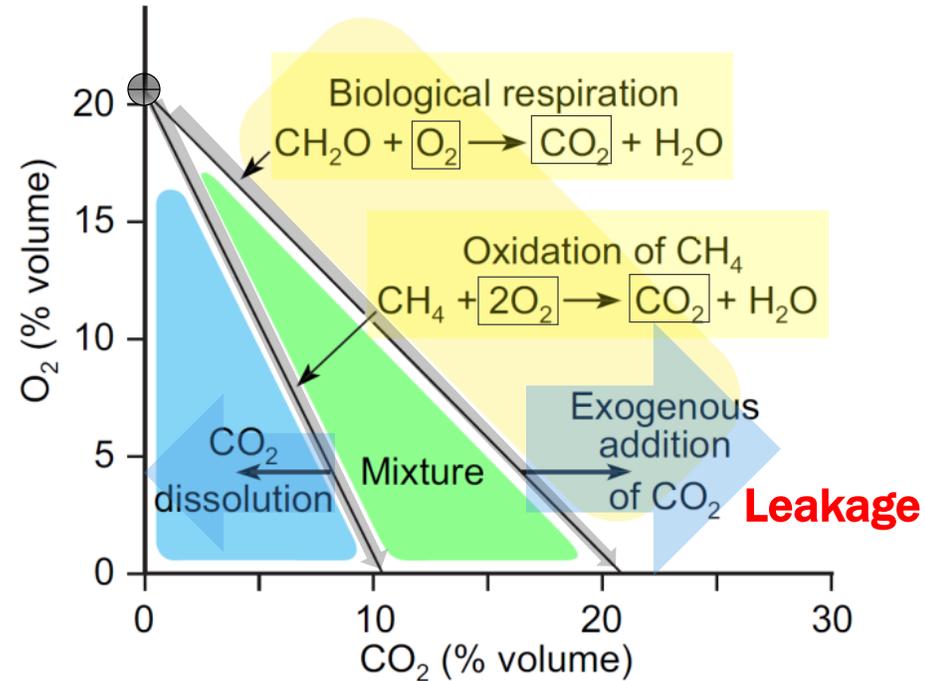
- Uses simple gas relationships to identify **processes**.
 - Biologic respiration
 - Methane oxidation
 - Dissolution
 - Leakage
- No need for years of background
- One time characterization
- Method can be applied in any environment regardless of variability



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

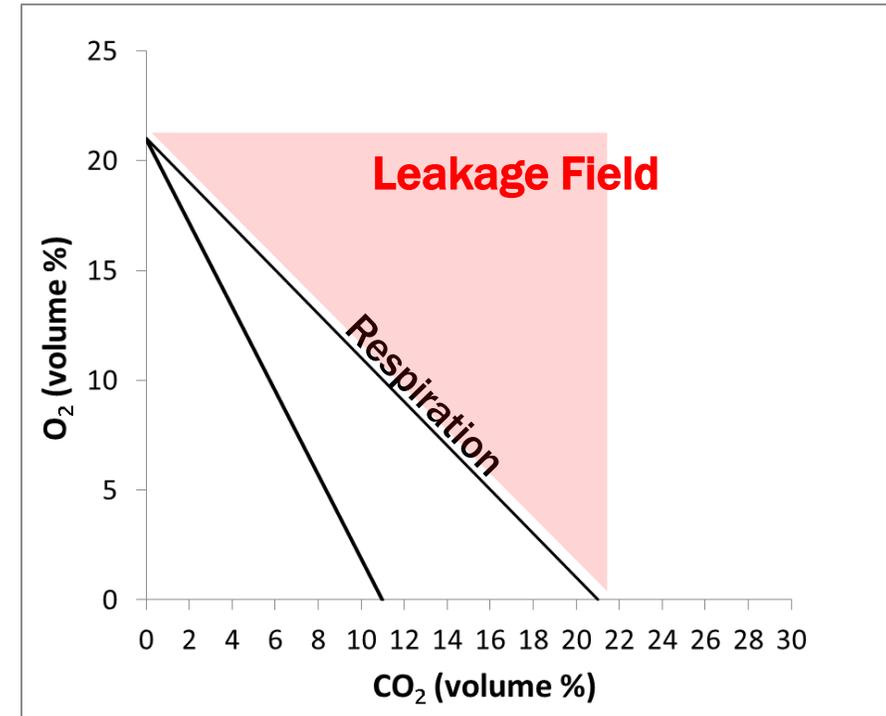
Process-Based Example

- Uses geochemical relationships to identify key processes rather than concentration comparisons



Ratios Providing “User-Friendly” Monitoring

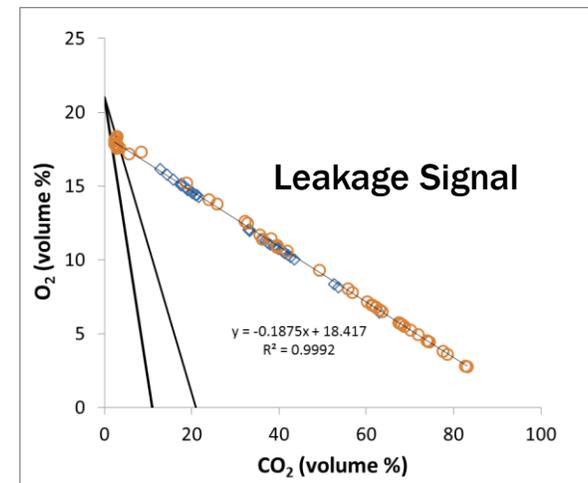
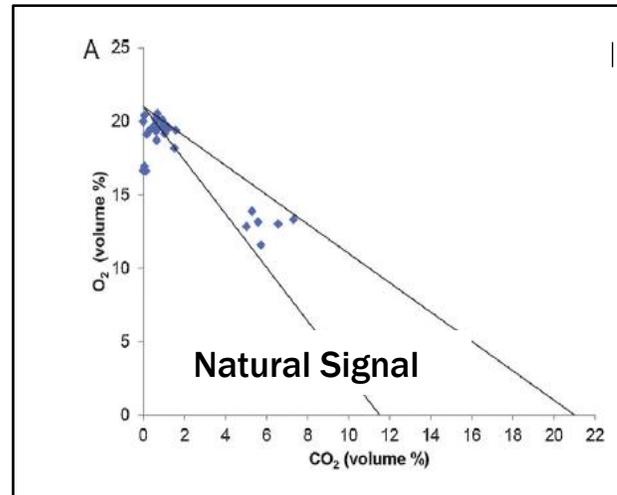
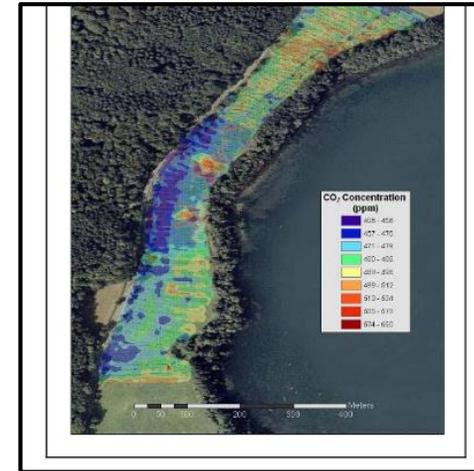
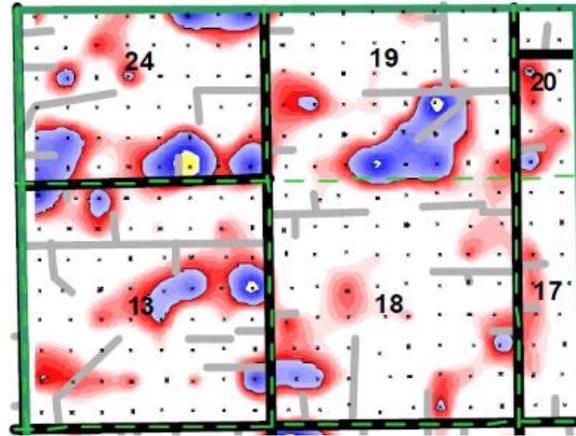
- Respiration line as a universal trigger point
- No need for years of baseline- only need a one-time characterization.
- Easy to explain and engage stakeholders
- Instant data reduction and graphical analysis



Katherine Romanak BEG

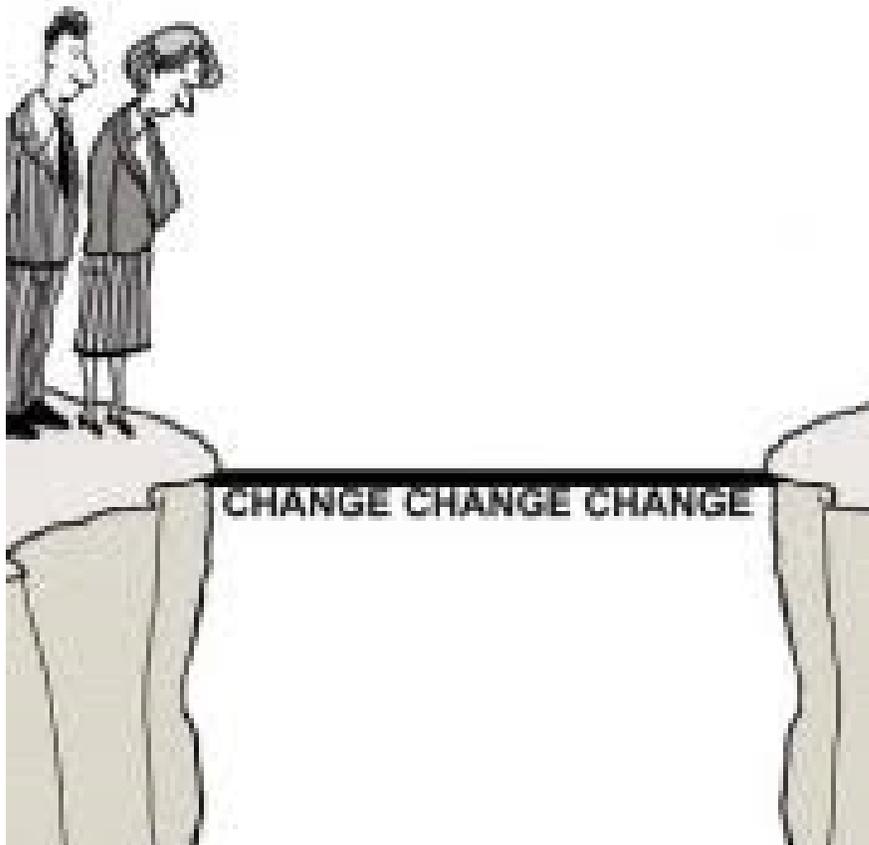
Process-based Attribution

B) CO₂ flux (g/m²/d) - October 2005



Learning from our Experience

Sometimes the reason you have to learn lessons the hard way is because you didn't learn your lesson the first time (the easy way).



Summary

- **CO₂ storage is safe by design**
- **Baselines should not be used for attribution! They are shifting due to climate change, will result in false positives for leakage, and will cause project shutdowns.**
- **Protocols and regulations need updating.**
- **The Kerr claim shows a great need for accurate methods and protocols for attribution for responding to stakeholders concerns.**
- **The risk of a false leakage claim is higher than the risk of actual leakage.**
- **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.**

Thank You

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<http://www.beg.utexas.edu/gccc/>

