Revelations in Monitoring

Why environmental monitoring isn't just for leakage anymore

Dr. Katherine Romanak
Research Scientist
The University of Texas at Austin

Main Questions from Stakeholders

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

Geologic CO_2 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

<u>Deep Subsurface – Verification</u>
Behavior conforms to predictions

<u>Shallow Subsurface - Assurance</u>
No unwanted outcomes to environment

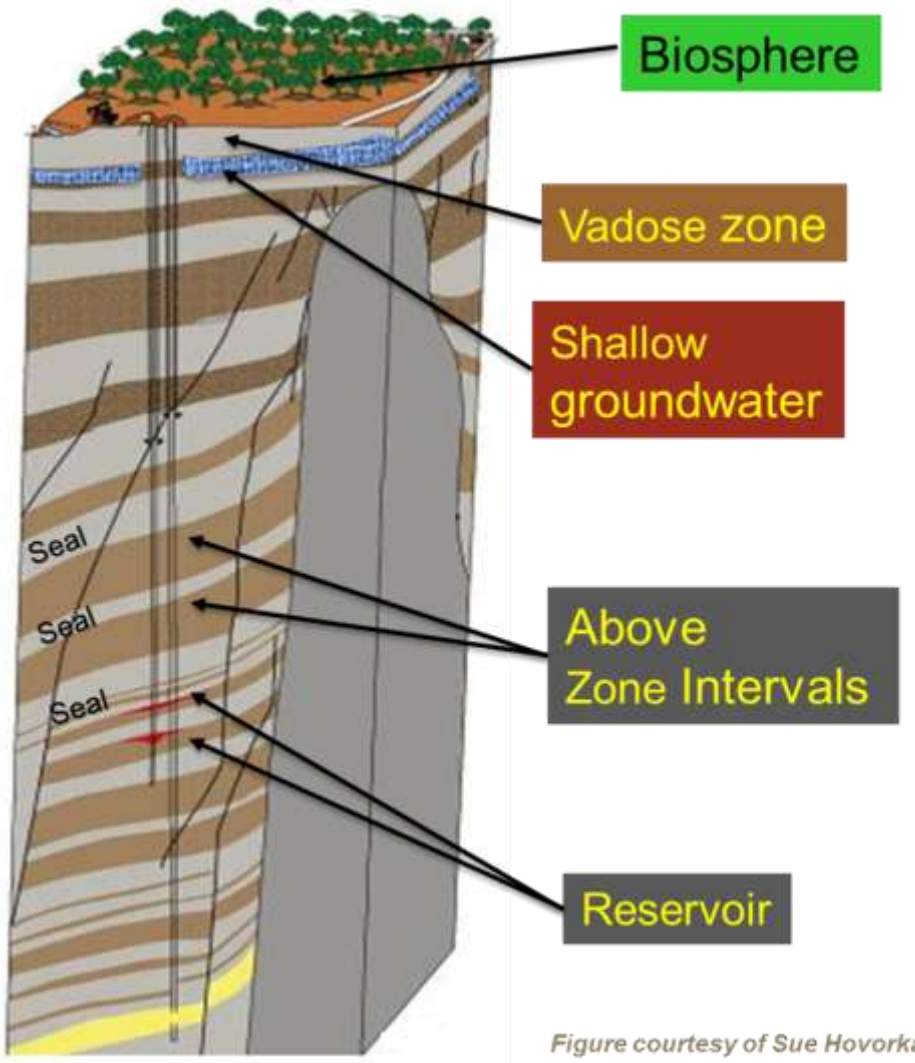
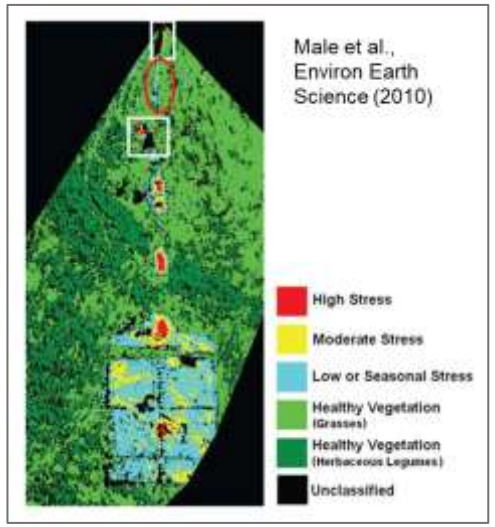


Figure courtesy of Sue Hovorka

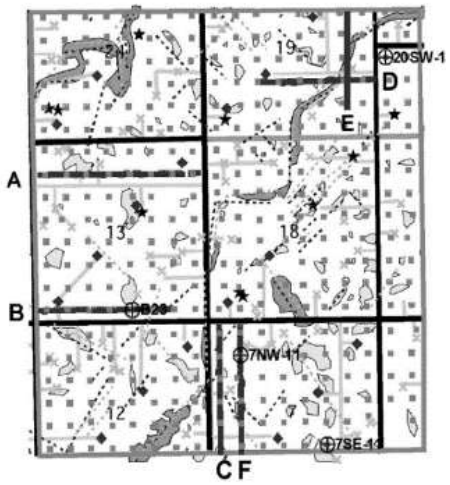
GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

The Lengths We Go To - Finding a Leak

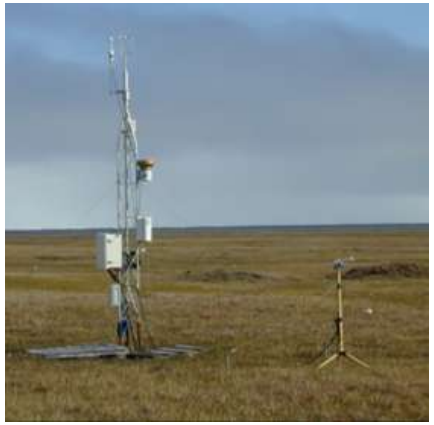
- Soil gas Grids
- Remote Sensing
- Drones/AUVs
- Sonar
- Open path lasers
- Eddy covariance
- Hyperspectral for Vegetation health



(Jones et al. 2009)

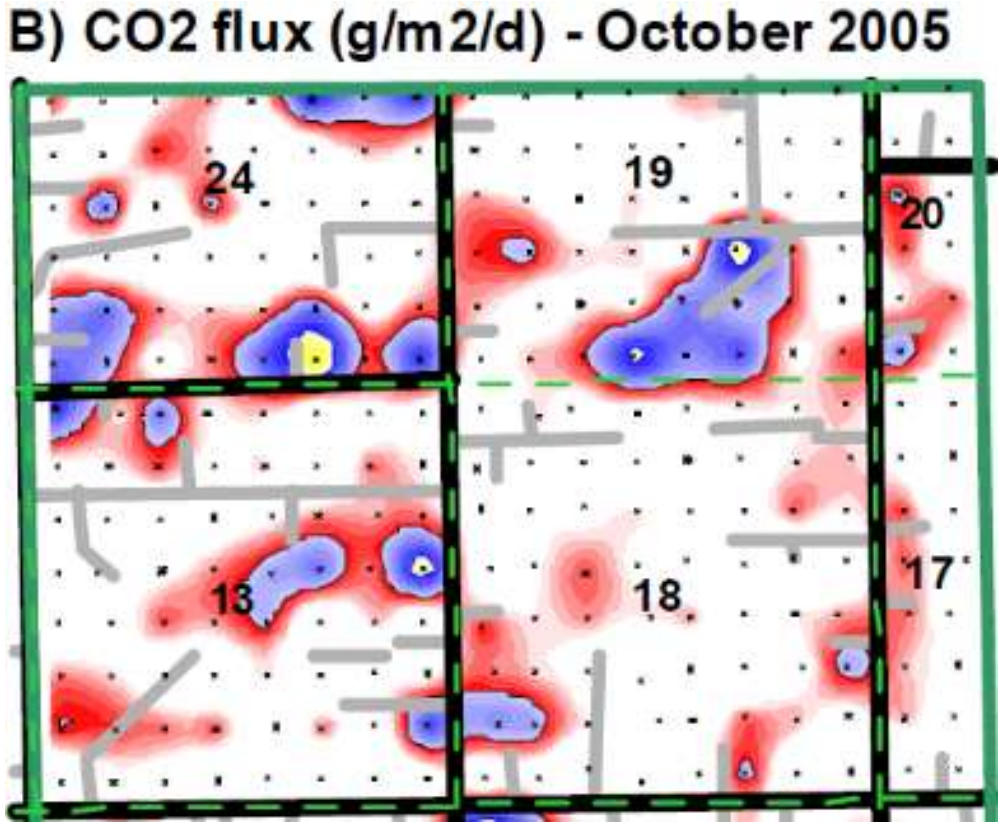


Weyburn soil-gas grid: 14 km^2, 200 m spacing (Riding and Rochelle, 2009).

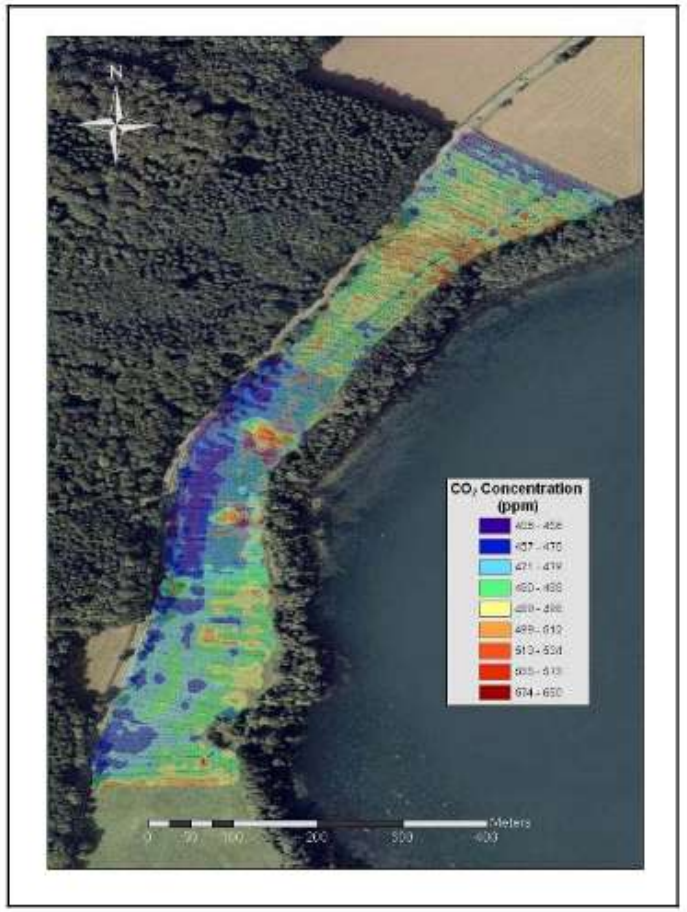


GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

CO_2 Source Attribution



Weyburn soil-gas grid: 14 km^2, 200 m spacing. Jones et al., 2006, Soil Gas Monitoring at the Weyburn Unit in 2005



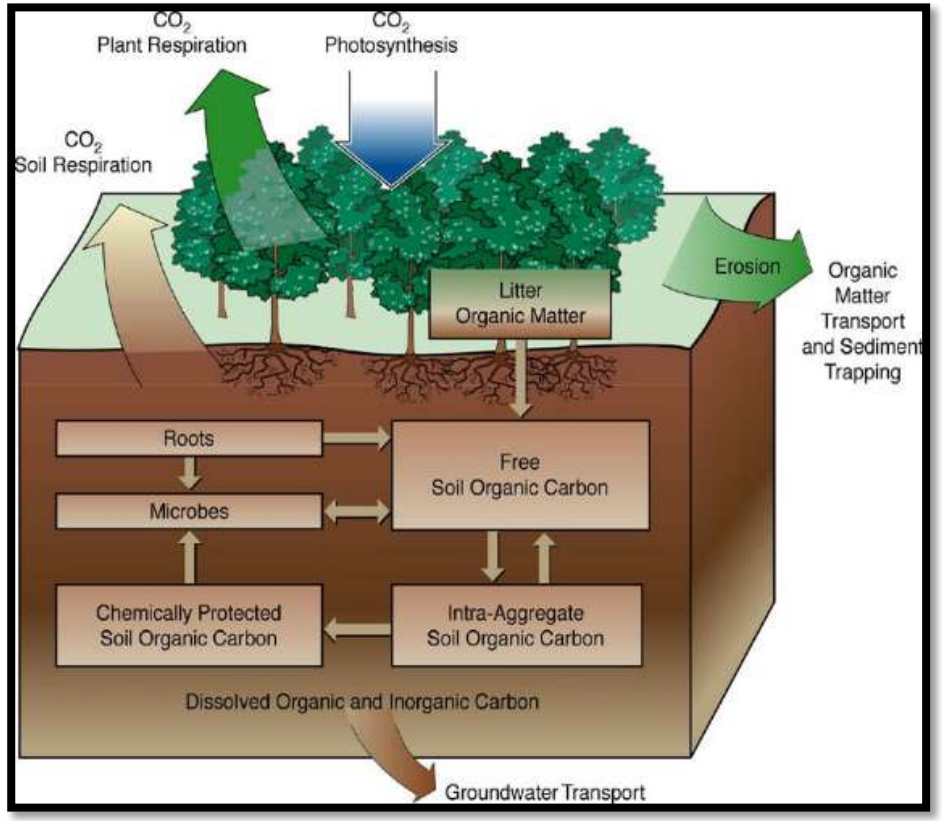
Walking traverses over gas vents at Latera with the ground surface measurement system (infrared analyzer) measuring CO2 concentrations (Jones et al. 2009)

GCCC GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY

CO_2 Variability

- CO_2 is naturally everywhere
- Dominant source is biological respiration
- Dynamic over space and time (temperature, rainfall, pressure…)
- CO_2 is reactive
- Very difficult to discern leakage from natural variability.
- Difficult to determine what is anomalous



Source: DOE, 1999: *Carbon Sequestration Research and Development*

GCCC GULF COAST CARBON CENTER | BUREAU OF ECONOMIC GEOLOGY

Determining Anomalies Using Baselines

- Measure "baseline" CO_2 for 1 year before project starts to document seasonal variability.
- Monitor CO_2 during project and compare to baseline.
- Significant increase from baseline during a project signals a leak anomalous CO_2

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

- Did the storage project cause the anomaly?
- "Attribution" is a missing step

GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

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	✓		✓			✓		✓

Dixon and Romanak, 2015, *International Journal of Greenhouse Gas Control*, *41*, 29-40.

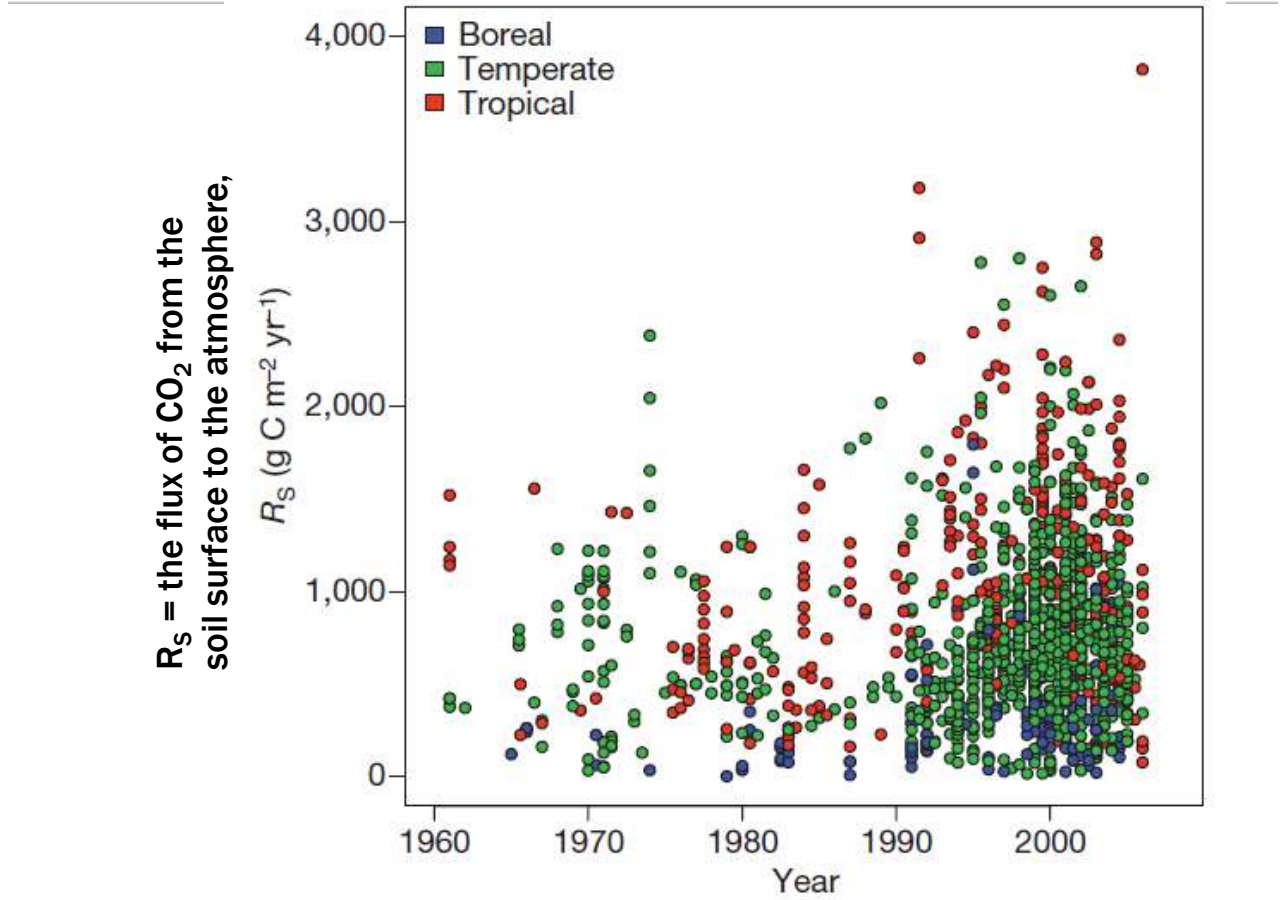
"Baselines" in Soils are Shifting Upwards

Vol 464|25 March 2010|doi:10.1038/nature08930 nature

Temperature-associated increases in the global soil respiration record

Ben Bond-Lamberty[1] & Allison Thomson[1]

R_S = the flux of CO_2 from the soil surface to the atmosphere,



GCCC GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY

“Baselines” in Groundwater are Shifting Upwards

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect
Geochimica et Cosmochimica Acta 72 (2008) 5581–5599

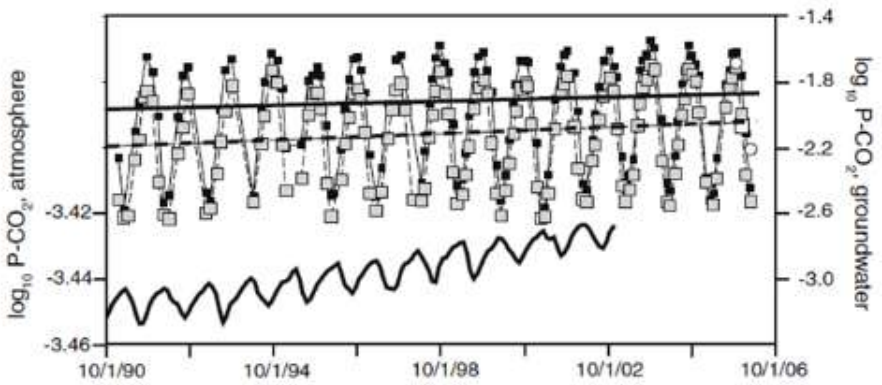
Geochimica et Cosmochimica Acta
www.elsevier.com/locate/gca

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

G.L. Macpherson [a,*], J.A. Roberts [a], J.M. Blair [b], M.A. Townsend [c], D.A. Fowle [a], K.R. Beisner [d]

[a] *Department of Geology, University of Kansas, 1475 Jayhawk Blvd., 120 Lindley Hall, Lawrence, KS 66045, USA*
[b] *Kansas State University, Manhattan, KS, USA*
[c] *Kansas Geological Survey, Lawrence, KS, USA*
[d] *University of Utah, Salt Lake City, UT, USA*

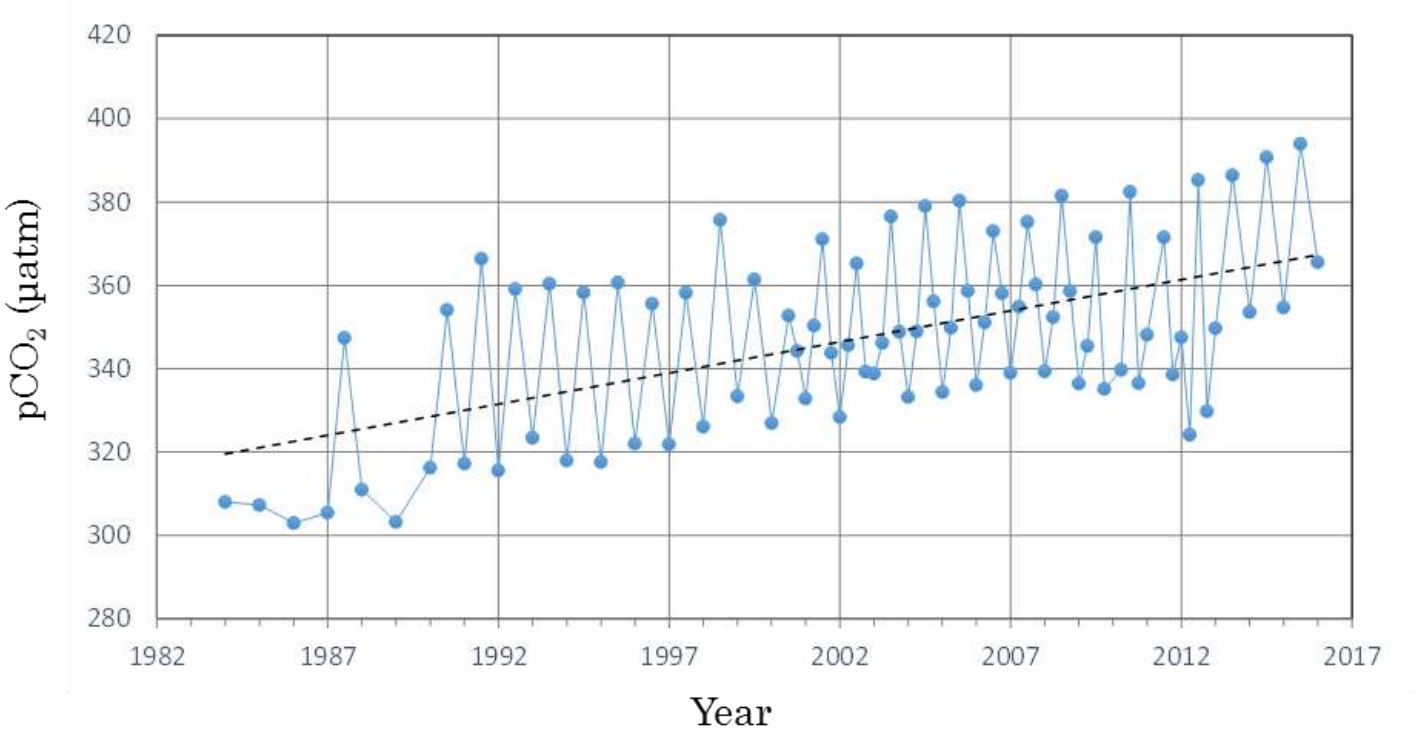
Received 28 January 2008; accepted in revised form 2 September 2008; available online 18 September 2008



Increased dissolution of CO_2 in groundwater and associated mineral dissolution

GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

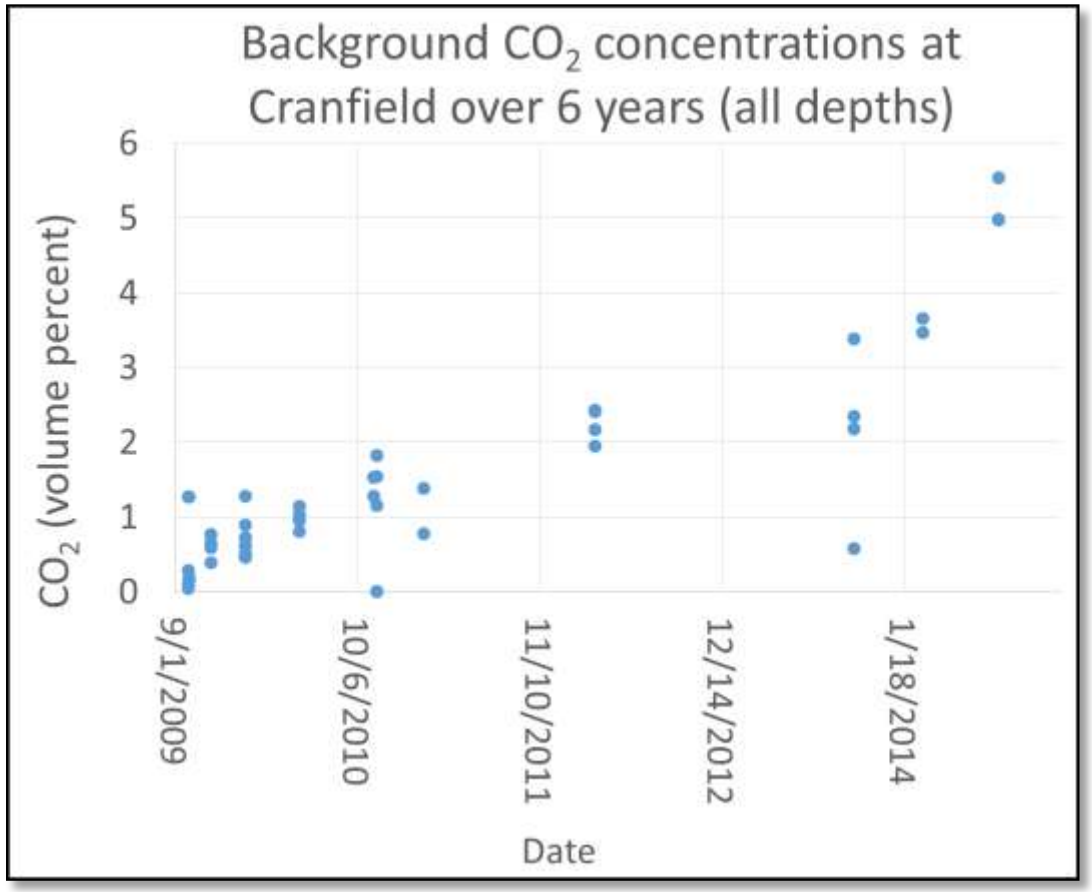
“Baselines” in Seawater are Shifting Upwards

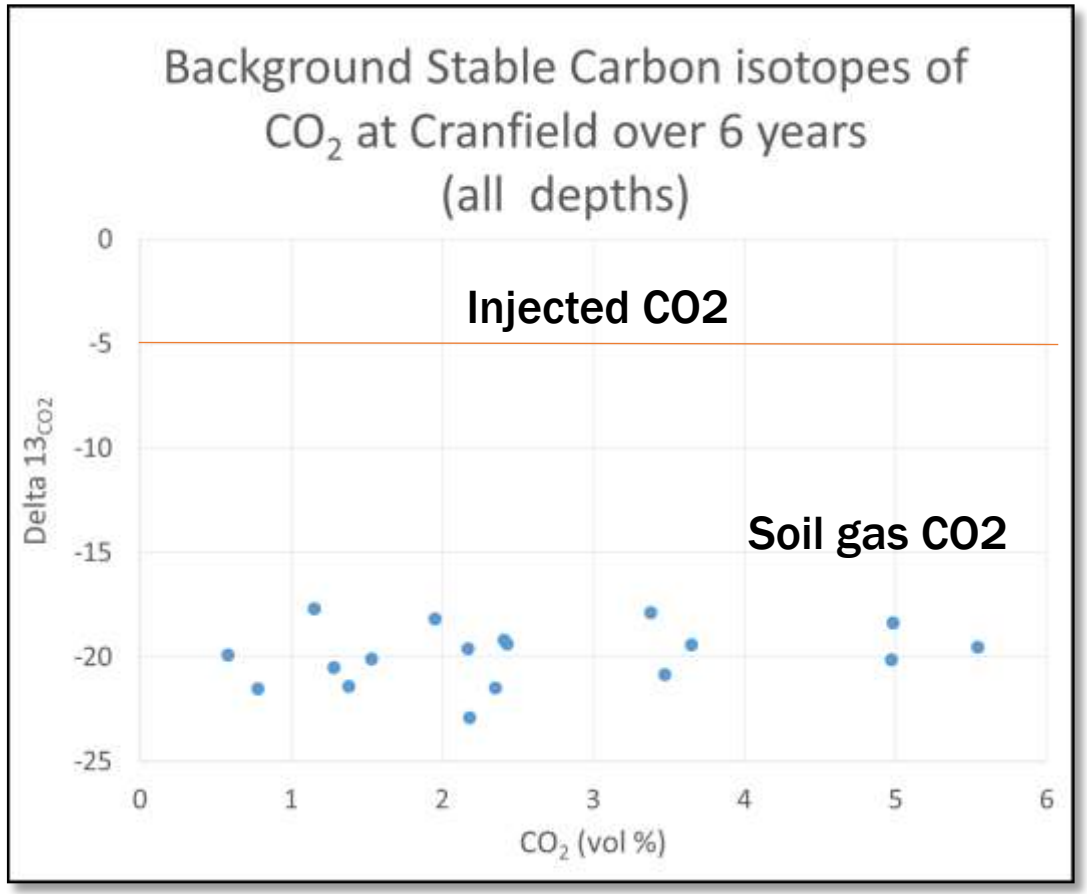


Time series of surface seawater CO_2 level near Japan. Source data by Japan Meteorological Agency, Courtesy of Jun Kita, RITE

GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

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





GCCC GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY

Revelation #1

- Naturally produced CO_2 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

GCCC GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY

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 CO_2 was injected
- High CO_2 levels observed in the routine monitoring
- February 2017 operations resumed

Shifting baselines cause false positives and project shutdowns

Slide courtesy of Jun Kita, MERI

Revelation #2

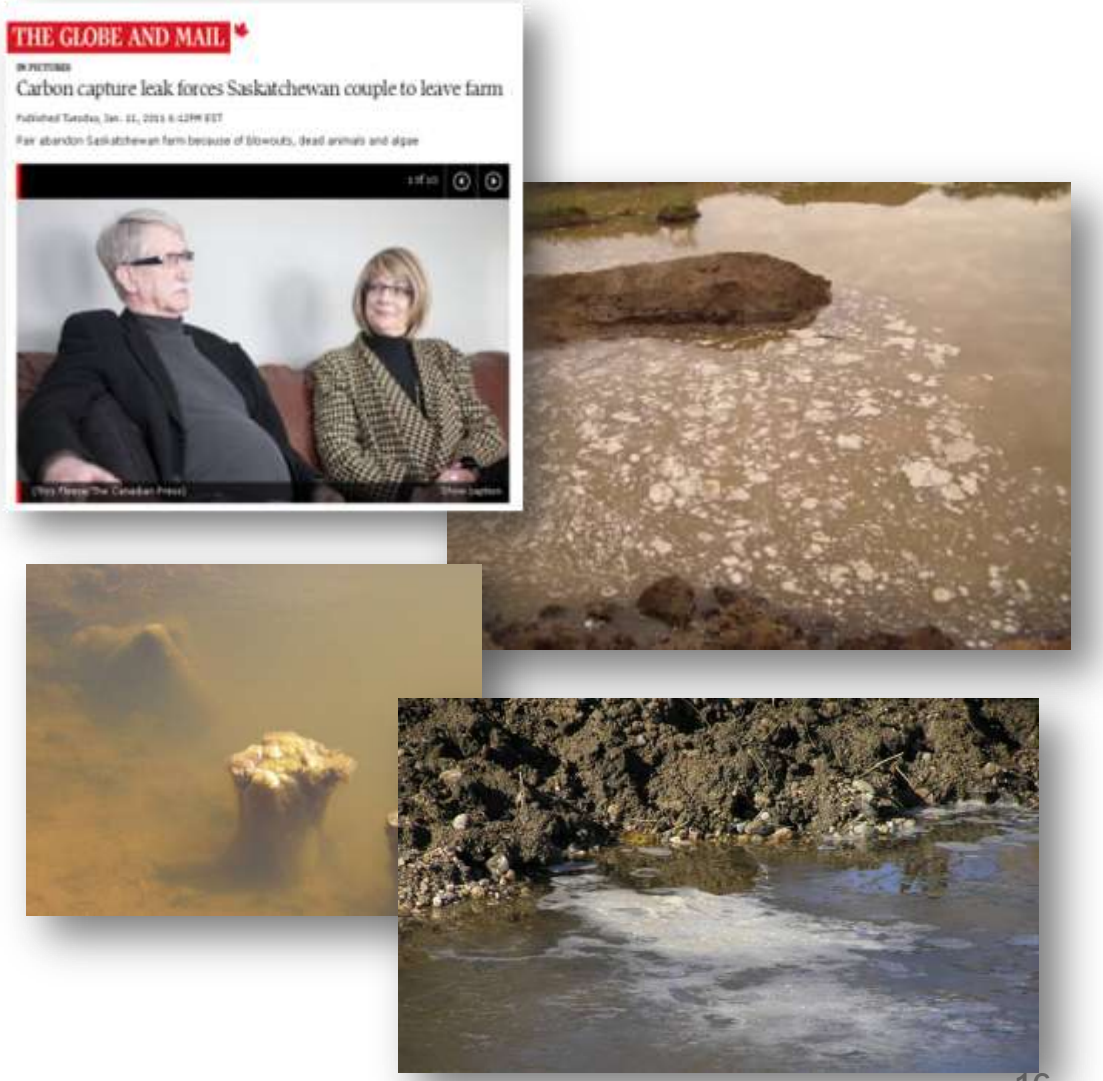
- If we actively look for “leakage” (e.g. via routine monitoring) we will find an abundance of natural anomalies
- We will need to attribute the source of these anomalies.
- Baseline methods are not effective or accurate.
- So how do we adequately assure environmental safety?

GCCC GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY

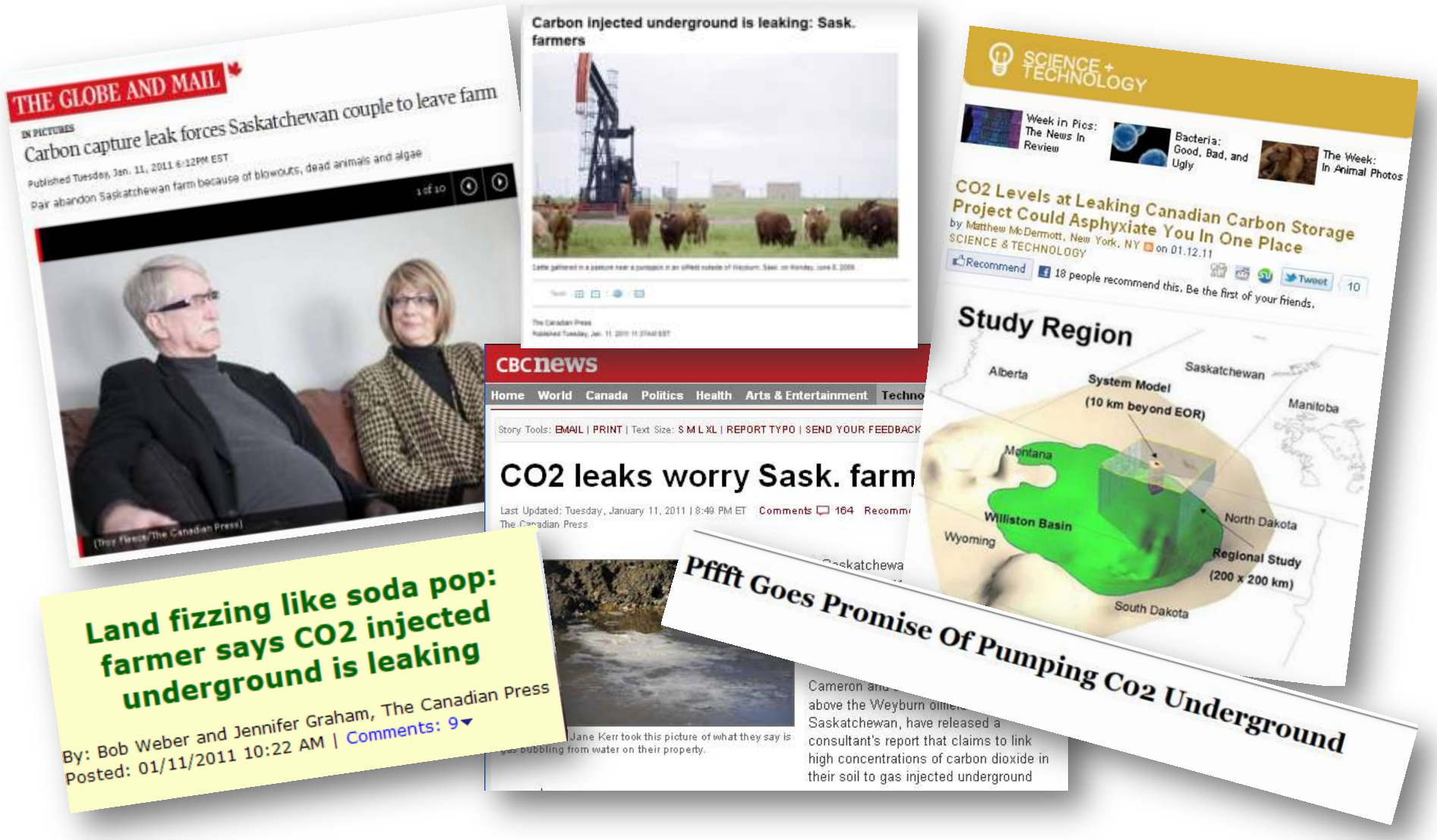
2011 Kerr Leakage Allegation

- IEAGHG Weyburn CO_2 Monitoring and Storage project, Saskatchewan Canada
- Perceived environmental change was blamed on the CO_2 storage project
- Protocols for responding to stakeholder concerns were not in place
- Unexperienced consultant wrongly attributed leakage



GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

Negative Media Storm

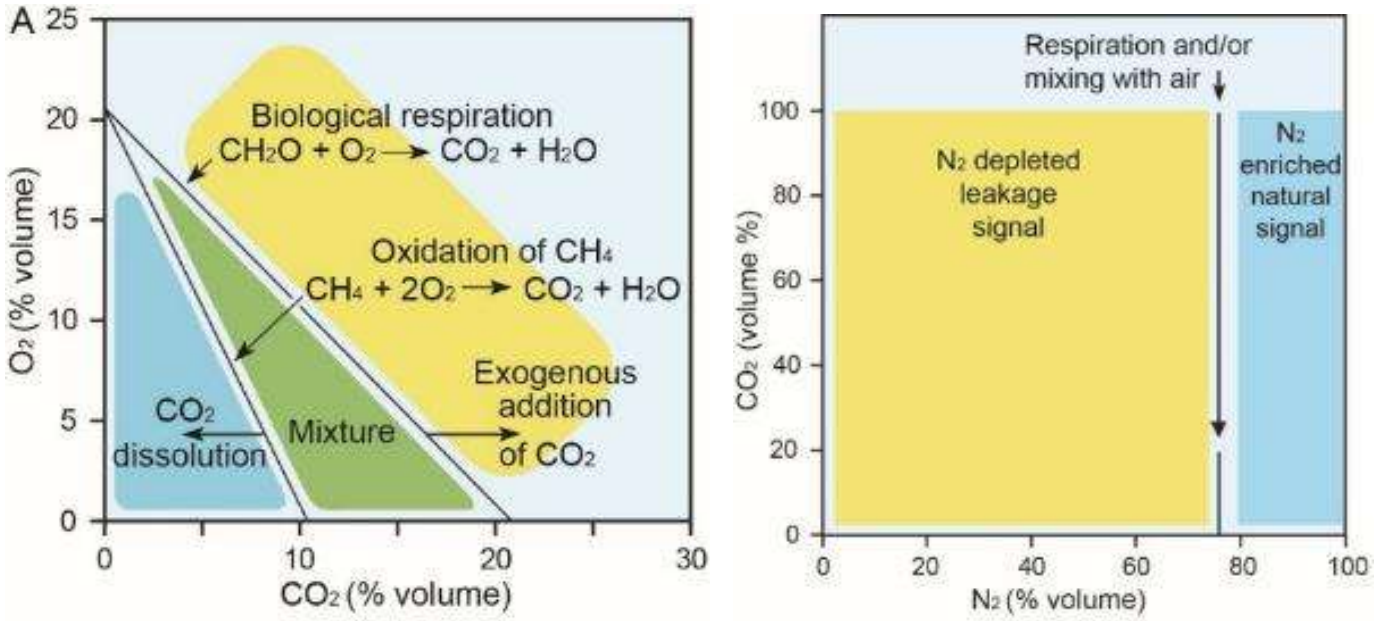


Revelation #3

- 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

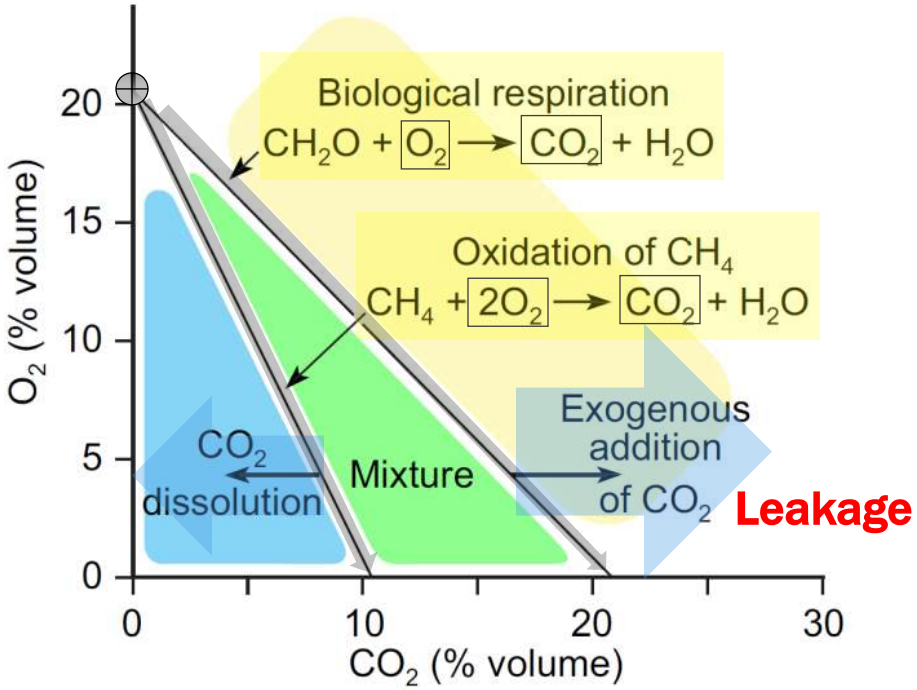


Romanak et al., 2014, International Journal of Greenhouse Gas Control, 30, 42-57
Romanak et al., 2012, Geophysical Research Letters, *39* (15).

GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

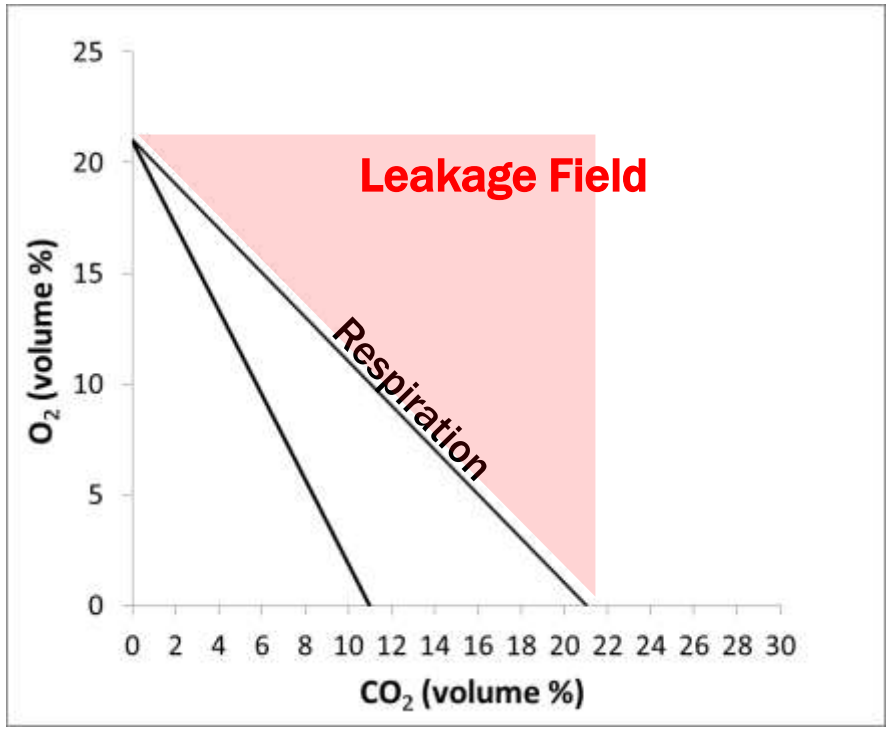
Process-Based Example

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



Ratios Providing "User-Friendly" Monitoring

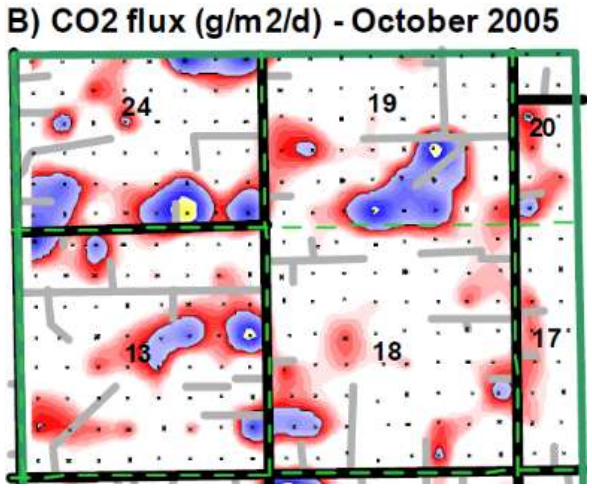
- Respiration line as a universal trigger point
- No need for years of baseline- only need a one-time characterization.
- Easy to explain and engage stakeholders
- Instant data reduction and graphical analysis

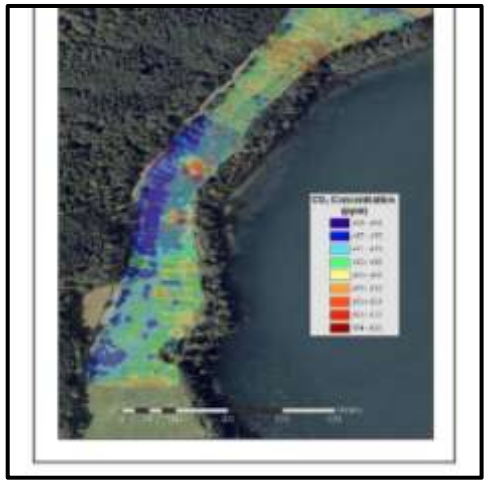


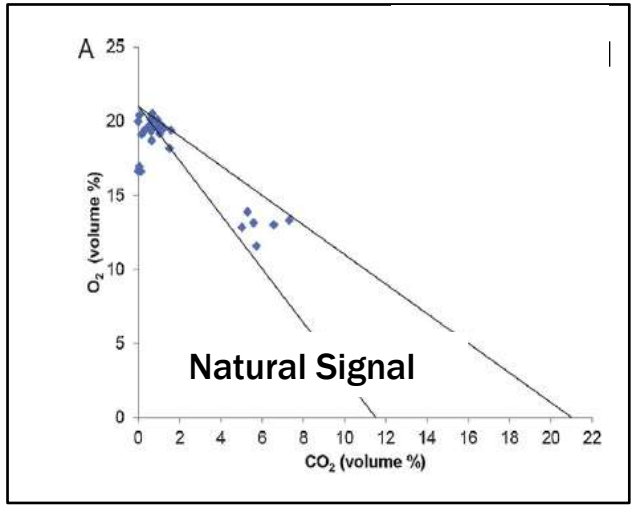
Katherine Romanak BEG

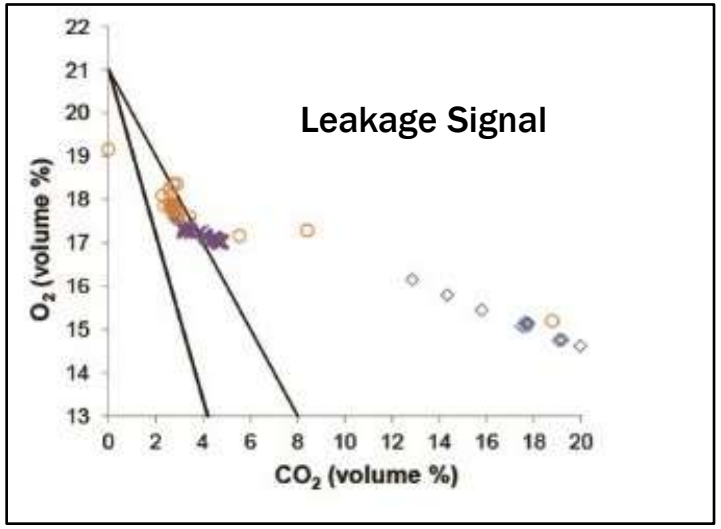
GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

Process-based Attribution



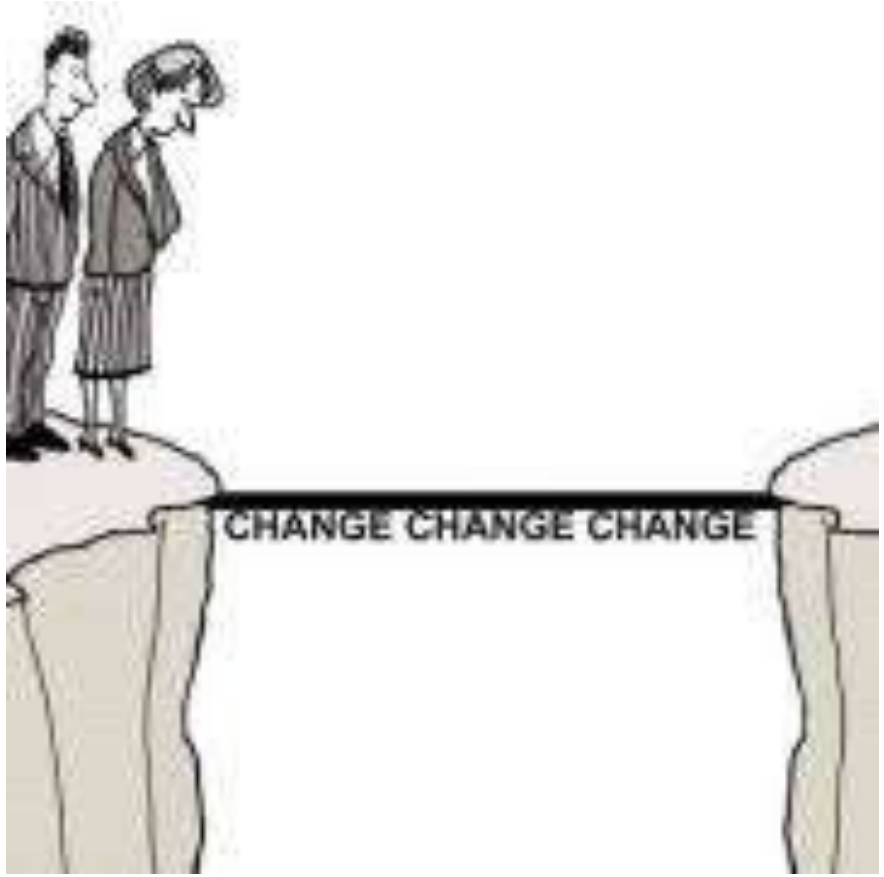






GCCC GULF COAST CARBON CENTER
BUREAU OF ECONOMIC GEOLOGY

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

- CO_2 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

Katherine Romanak
Gulf Coast Carbon Center
Bureau of Economic Geology
The University of Texas at Austin

katherine.romanak@beg.utexas.edu

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